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Samuel Hubbard.

THE

WORKING-MAN'S COMPANION.

THE RESULTS OF MACHINERY.

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THE

WORKING-MAN'S COMPANION.

THE

RESULTS OF MACHINERY,

NAMELY,

CHEAP PRODUCTION

AND

INCREASED EMPLOYMENT, EXHIBITED:

BEING

AN ADDRESS TO THE WORKING-MEN OF THE UNITED KINGDOM.

AMERICAN EDITION.

Philadelphia:
CAREY & HART.—CHESTNUT STREET.
1831.

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THE

RESULTS OF MACHINERY.

CHAPTER I.

In the year 1827, a Committee of the House of Commons was appointed to examine into the subject of emigration—that is, to see whether it was desirable and practicable to remove distressed laborers from the United Kingdom to distant places, where their labor might be profitably employed to themselves and others. The first person examined before that Committee was Joseph Foster, a working weaver, of Glasgow. He told the Committee, that he and many others, who had formed themselves into a society, were in great distress; that numbers of them worked at the *hand-loom* from eighteen to nineteen hours a-day, and that their earnings, at the utmost, did not amount to more than seven shillings a-week, and that sometimes they were as low as four shillings. That twenty years before that time they could readily earn a pound a-week by the same industry; and that as *power-loom* weaving had increased, the distress of the hand-weavers also had increased in the same proportion. A power-loom is one worked

by machinery, and led by the hand of man, as most of our readers perhaps know. The Committee then put to Joseph Foster the following questions, and received the following answers :—

Q. " Are the Committee to understand that you attribute the insufficiency of your remuneration for your labor to the introduction of machinery ?

A. Yes.

Q. Do you consider, therefore, that the introduction of machinery is objectionable ?

A. We do not. The weavers in general, of Glasgow and its vicinity, do not consider that machinery can or ought to be stopped, or put down. They know perfectly well that machinery must go on, that it will go on, and that it is impossible to stop it. They are aware that every implement of agriculture or manufacture is a portion of machinery, and, indeed, everything that goes beyond the teeth and nails (if I may use the expression) is a machine. I am authorized, by the majority of our society, to say, that I speak their minds, as well as my own, in stating this."

If all, or if a large majority of the working-men of our country had come to the same sound opinions as Joseph Foster, we should not take the trouble, because it would be needless, now to address them. But when we hear on all sides, that misguided men are violating the laws by which the rights of all are protected; that they are wickedly and ignorantly

destroying the property of the farmer and the manufacturer, in the belief that machinery *can* be stopped or put down; that they do *not* know as the poor weavers of Glasgow *did* know, that machinery must go on, will go on, and that it is impossible to stop it; we think it our duty, having the means of appealing to their reason and to their regard for their own interest, to endeavor to bring their minds to the same conclusions as those of the respectable weaver, whose words we have repeated. He felt that, although he was in his own person a sufferer from the improvement of machinery, it was utterly out of his power, because it was contrary to his reason, and to the reason of all thinking people, whether working-men or not, to resist the progress of that improvement. There are many working-men who entertain the same sound opinions, which they have come to, probably, by an accurate and dispassionate observation of the facts which are within their own view. To such men we hope to offer many new facts to strengthen their opinions; and we rely greatly upon their influence to point out their errors, either to those who are violating the laws, or to those who think the violators of the laws have justice on their side. For the benefit of you all, the informed as well as the uninformed, we address you as men capable of reasoning. We give you a great body of facts to reason upon. We offer nothing to your passions or your prejudices. We shall attempt to make you feel, by bringing before you the same sort of facts by which

that sensible man, Joseph Foster, convinced his own mind, that although your individual labor may be partially displaced, or unsettled for a time, by the use of a cheaper and a better power, which power is machinery, you are great gainers by the general use of that power. We shall strive to show you, that through this power you possess, however poor you may be, many of the comforts which make the difference between man in a civilized and man in a savage state; and further that, in consequence of machinery having rendered productions of all sorts cheaper, and therefore caused them to be more universally purchased, it has really increased the demand for that manual labor, which it appears to some of you, reasoning only from a few instances, it has a tendency to diminish. If we make out these propositions, we think you will agree with Joseph Foster, that the introduction of machinery is not objectionable.

The difference between those of you who object to machines, and the persons who think with Joseph Foster, is, as it appears to us, a want of knowledge. We desire to impart to you that knowledge. Now, how shall we set about the business of imparting it? You are many in number, and are scattered over a large extent of country; some of you are sorely pressed, as we conceive, by the evils that result from a want of knowledge, which make it the more necessary that we should address ourselves to you speedily; and some of you are poor, and therefore have not much to spare, even

for what you may believe may do you good. You, therefore, want this knowledge to be given to you, *extensively*, *quickly*, *cheaply*. It would be out of our power to impart this knowledge *at all* without machinery: and, therefore, we shall begin by explaining how the machinery, which gives you *knowledge* of any sort by the means of books, is a vast blessing, when compared with slower methods of multiplying written language; and how, by the aid of this machinery, we can produce a book for your use, without any limit in point of the number of copies, with great rapidity, and at a small price.

It is about 350 years since the art of printing books was invented. Before that time all books were written by the hand. There were many persons employed to copy out books, but they were very dear, although the copiers had small wages. A Bible was sold for thirty pounds in the money of that day, which was equal to a great deal more of our money. Of course, very few people had Bibles or any other books. An ingenious man invented a mode of imitating the written books by cutting the letters on wood, and taking off copies from the wooden blocks by rubbing the sheet on the back; and soon after other clever men thought of casting metal types or letters, which could be arranged in words, and sentences, and pages, and volumes; and then a machine, called a printing-press, upon the principle of a screw, was made to stamp impressions of these types so arranged. There was an end,

then, at once, to the trade of the pen-and-ink copiers; because the copiers in types, who could press off several hundred books while the writers were producing one, drove them out of the morket. A single printer could do the work of at least two hundred writers. At first sight this seems a hardship, for a hundred and ninety-nine people might have been, and probably were, thrown out of their accustomed employment. But what was the consequence in a year or two? Where one written book was sold, a thousand printed books were required. The old books were multiplied in all countries, and new books were composed by men of talent and learning, because they could then find numerous readers. The printing-press did the work more neatly and more correctly than the writer, and it did it infinitely cheaper. What then? The writers of books had to turn their hands to some other trade, it is true; but type-founders, paper-makers, printers, and bookbinders, were set to work, by the new art or machine, to at least a hundred times greater number of persons than the old way of making books employed. If the pen-and-ink copiers could break the printing-presses, and melt down the types that are used in London alone at the present day, twenty thousand people would at least be thrown out of employment to make room for two hundred at the utmost; and what would be even worse than all this misery, books could only be purchased, as before the invention of printing, by the few rich, instead

of being the guides, and comforters, and best friends, of the millions who are now within reach of the benefits and enjoyments which they bestow.

The *cheapness of production* is the great point to which we shall call your attention, as we give you other examples of the good of machinery. In the case of books produced by the printing-press you have a cheap article, and an increased number of persons engaged in manufacturing that article. In almost all trades the introduction of machines has, sooner or later, the like effects. This we shall show you as we go on. But to make the matter even more clear, we shall direct your notice to the very book you hold in your hand, to complete our illustration of the advantages of machinery to the consumer, that is, to the person who wants and buys the article consumed, as well as to the producer, or the person who manufactures the article produced.

This little book is intended to consist of 216 pages, to be printed, eighteen on a side, upon six sheets of printing paper, called by the makers demy. These six sheets of demy, at the price charged in the shops, would cost fourpence. If the same number of words were written, instead of being printed—that is, if the closeness and regularity of printing were superseded by the looseness and unevenness of writing,—they would cover 200 pages, or 50 sheets, of the paper called foolscap, which would cost in the shops three shillings; and you would have a book difficult instead of easy to read,

because writing is much harder to decipher than print. Here, then, besides the superiority of the workmanship, is at once a saving of two shillings and eight pence to the consumer, by the invention of printing, all other things being equal. But the great saving is to come. Work as hard as he could, a writer could not transcribe this little book upon these 200 pages of foolscap in less than ten days; and he would think himself very ill paid to receive thirty shillings for the operation. Adding, therefore, a profit for the publisher and retail tradesman, a single written copy of this little book, which you buy for a shilling, could not be produced for two pounds. Is it not perfectly clear, then, if there were no printing-press, if the art of printing did not exist, that if we found purchasers at all for this dear book at the cost of two pounds, we should only sell, at the utmost, a fortieth part of what we now sell; that instead of selling ten thousand copies we could only sell, even if there were the same quantity of book-buying funds amongst the few purchasers as amongst the many, two hundred and fifty copies; and that therefore, although we might employ two hundred and fifty writers for a week, instead of about twenty printers in the same period, we should have forty times less employment for paper-makers, ink-makers, book-binders, and many other persons, besides the printers themselves, who are called into activity by the large demand which follows cheapness of production.

You will perceive, without having the subject dwelt upon, that if we could not give you this book *cheaply*, we could not give it you *extensively;* that, in fact, the book would be useless; that it would be a mere curiosity; that we should not attempt to multiply any copies, because those whose use it was intended for could not buy it. It is also perfectly clear, that if, by any unnatural reduction of the wages of labor, such as happens to the Hindoo, who works at weaving muslin for about sixpence a week, we could get copiers to produce the book as cheaply as the printing-press, (which is impossible,) we could not send it to the world as *quickly*. We can get ten thousand copies of this book printed in a week, by the aid of about twelve compositors, and two printing machines, each machine requiring two boys and a man for its guidance. To transcribe ten thousand copies in the same time would require more than ten thousand penmen. Is it not perfectly evident, therefore, that if printing, which is a cheap and a rapid process, were once again superseded by writing, which is an expensive and a slow operation, neither this book, nor any other book, could be produced for the use of the people; that knowledge, upon which every hope of bettering your condition must ultimately rest, would again become the property of a very few; and that mankind would lose the greater part of that power, which has made, and is making them, truly independent, and which will make them virtuous and happy?

The same principle applies to any improvement of the machinery used in printing, or in the manufacture of the paper upon which books are printed. By the use of the printing machine, instead of the printing press, (which machine is only profitably applicable to books printed in large numbers,) the cost of production is diminished at least one-tenth; and by the use of the machine for making paper, a better article is produced, also at a lower rate. This book is printed upon paper as fine as is needful for comfortable reading, instead of paper of a wretched quality; because the paper-machine has diminished the cost of production, by working up the pulp of which paper is composed more evenly, and therefore with a saving. And from both causes united, the diminished price of printing by the machine instead of printing by hand, and the diminished price of machine-made paper, the buyers of this book have six sheets, or 216 pages, instead of five sheets, or 180 pages, for a shilling. Thus, not only is the price lessened to the consumer, by the increase of the quantity, but one-sixth more paper, one-sixth more ink, one-sixth more labor of the compositor or printer who arranges the types, one-sixth more labor of the sewer or binder of the book; all these additions of direct labor and of materials produced by labor are consumed. In selling you this book, therefore, for a shilling, we give you a sixth more matter than you could have had without these new inventions: if we were to take away that sixth in quantity,

we could lessen the price, and give you the smaller book for tenpence. Thus, then, there is a decided advantage to the consumer in the diminished cost of the production, and an ample equivalent in mere labor, (which, bear always in mind, is the means of producing commodities, and not the end for which they are produced,) in the place of labor thrust out by the printing-machine and the paper-machine.

We cannot conclude this branch of our subject without one other illustration. About seven years ago the art of engraving on steel was invented: this art arose out of an attempt to multiply plates by machinery. It was said that this art would ruin the engravers as a body; for as steel-plates would not wear out with printing twenty thousand copies, and copper-plates could not give more than a thousand impressions, one steel-plate would stand in the place of twenty copper ones. Yet engravers, as a body, were never so numerous or so flourishing as they are at this moment; simply because steel-plates having made engravings cheap, numbers can have the pleasure of possessing prints, which were formerly only within the reach of a very few. The class of books called Annuals, which consist each of ten or twelve beautiful engravings, with amusing reading, at a moderate price, and of which at least one hundred thousand copies are sold, having cost in their production about £50,000, could never have existed without the invention of steel engraving; and there are many other

publications of landscapes, views of buildings, maps, &c. which, being rendered cheap by steel engravings, have produced exactly the same effects of increasing the enjoyments of the consumers, and bettering the condition and increasing the numbers of the producers.

We think that in the article of *Books* we have proved to you that machinery has rendered productions cheaper, and has increased the demand for manual labor, and consequently the number of laborers; and that, therefore, machinery applied to books is not objectionable. We proceed from books to articles of actual necessity.

CHAPTER II.

Amongst the many accounts which the newspapers of December, 1830, give of the destruction of machinery by agricultural laborers, we read that in the neighborhood of Aylesbury, a band of mistaken and unfortunate men destroyed all the machinery of many farms, *down even to the common drills.* The men conducted themselves, says the county newspaper, with civility; and such was their consideration, that they moved the machines out of the farm-yards, to prevent injury arising to the cattle from the nails and splinters that flew about while the machinery was being destroyed. They *could not make up their minds* as to the propriety of destroying a horse-churn, and therefore that machine was passed over.

We will suppose, by way of argument, that

there were no laws to repress such outrages; that if the laborers in agriculture chose to believe, that not only thrashing machines were injurious to them, but that every one of those ingenious implements which have aided in rendering British agriculture the most perfect in the world, was equally harmful, they might, without interruption, break them to pieces. We will further suppose, that while these proceedings go forward, the landowner looks on, the farmer looks on, the magistrate does not stir, there are no judges or juries in the land, the people in the towns leave the machine-breakers to their own devices. So they break on—thrashing machine, winnowing machine, chaff-cutting machine, drill, and every other new-fangled invention, as they call these things. We will suppose, still further, that the farmer yields to all this violence; that the violence has the effect which it was meant to have upon him; and that he takes on all the hands which were out of employ, to thrash and winnow, to cut chaff, to plant with a dibber instead of with a drill, to do all the work, in fact, by the dearest mode instead of the cheapest. The destroyers of property have got the law, therefore, into their own hands, as far as their triumph over machinery is concerned. And how do they proceed in their career? The farmer, we have imagined, takes all this quietly; he pays the new laborers who have got into his barns and his fields, ready for hand-work, with their flails and their dibbers; but he employs *just as many people as are abso-*

lutely necessary, and no more, for getting his corn ready for market, and for preparing, in a slovenly way, for the seed-time. In a month or two, the victorious destroyers find that not a single hand the more of them is really employed. And why not? There are no drainings going forward, the hedges and ditches are neglected, the dung-heap is not turned over, the chalk is not fetched from the pit; in fact, all those labors are neglected which belong to a state of agricultural industry which is brought to perfection. *The farmer has no funds to employ in such labors;* he is paying a great deal more than he paid before, because his laborers choose to do certain labors with rude tools instead of perfect ones. If he is a humane man, but not a firm one, and yields to the notion that it is a good thing to do work in the most round-about way, and, consequently, at the greatest expense, he does not regret the loss of the drill-plow, which, as well as many other agricultural tools, lessens labor, lessens the quantity of seed, and increases the crop. He spends all the saving which the drill-plow has caused upon the clamorous laborers, who insist that their arms are better for his work than the instrument which they have broken. But still some work must be neglected, and thus the actual amount of money paid for labor is just the same.

We will imagine that this state of things continues till the next spring. All this while the price of grain has been rising. Many farmers have ceased to employ capital at all upon

the land. The neat inventions, which enabled them to make a living out of their business, being destroyed, they have abandoned the business altogether. Others, who have yielded to the uproar, go on as well as they can, neglecting a great many labors that unite to make a good crop, although they are more and more pressed upon by the demand for labor, in consequence of a deal of land going out of cultivation. They pay as long as they can; they pay much more for labor than they did before, some out of compassion and some out of fear. But the prices are steadily rising, and, therefore, although there is more money paid to a greater number of laborers, and although some receive higher wages, in the common sense of the word, than they did before they broke the machines, they are infinitely worse off, for the rate of wages is really lower. A day's work will then no longer purchase as much bread as before. It requires the work of a day and a half to procure the same quantity. Wages are, therefore, really lower, because a less crop is being produced at a greater cost, and the market-price is influenced accordingly.

The laborers now either begin to quarrel among themselves, and give up their unwise combinations; or they still combine with the determination to obtain employment by the destruction of every thing that appears to them to stand in the way of it,—every thing beyond the teeth and nails of the workmen, as Joseph Foster expressed himself—and on they

go in the work of ruin. The horse, it may be probably found out, is as great an enemy as the drill-plow; so the horses are turned out to starve, or have their throats cut, the laws being still idle. This is, indeed, a great point gained, for as a horse will do the field-work of six men, there must be six men employed, without doubt, instead of one horse: so would conclude these most mistaken violators of the laws by which society is held together. But how would the fact turn out? If the farmer still went on, in spite of all these losses and crosses, he might employ men in the place of horses, but not a single man more than the number that would work at the price of the keep of one horse. To do the work of each horse destroyed he would require six men; but he would only have about a shilling a day to divide between these six,—the amount which the horse consumed.

In the mean time it would be perfectly evident, from all this convulsion amongst the laborers, from all this wanton and profitless ruin, that a great deal of the land would very quickly go out of cultivation altogether, if the laws were still idle. While the land was going out of cultivation, the stock of corn on hand would be much more quickly decreasing than in quiet times. One-tenth, it is said by some, would be lost of that stock by employing flails instead of thrashing machines. This is, probably, an extreme statement, grounded only upon a comparison between the regular produce of the thrashing machine, and the most careless

thrashing by the flail. But there is no doubt that the machine saves some corn. The destruction of drills, also, would cause a larger quantity of seed to be sown than would be otherwise necessary. Thrashing machines and drills, taken together in their savings, prevent therefore some thousand quarters of wheat alone from being wasted. Fifteen million quarters of wheat are annually consumed in Great Britain. If they save only a fiftieth of the wheat, as much, therefore, as would feed all the people of Great Britain for a week, or three hundred thousand of those people all the year, would be absolutely thrown away, trodden under foot, sent to the dunghill with the straw, wasted for ever, by one wrong act alone of the laborers; and all this while we should be preparing to grow a great deal less for the next harvest. We should have a famine, if foreign countries could not supply us with what the laborers had destroyed. And how do we know that foreign laborers would be wiser than the English ones, and abstain from such acts, in the knowledge that whatever raises the price of produce lowers the rate of wages? Are foreign laborers better informed than English laborers? If so, let us all take shame to ourselves, that the means of acquiring knowledge which this country affords have been neglected; for upon sound knowledge must rest the safety and happiness of all.

About three or four hundred years ago, from the times of king Henry IV. to those of king Henry VI., and, indeed, long before

these reigns, there were often grievous famines in this country, because the land was very wretchedly cultivated. Men, women, and children perished of actual hunger by thousands; and those who survived kept themselves alive by eating the bark of trees acorns, and pig-nuts. There were no machines then; but the condition of the laborers was so bad, that they could not be kept to work upon the land without very severe and tyrannical laws, which absolutely forbade them to leave the station in which they were born as laborers, for any hope of bettering their condition in the towns. There were not laborers enough to till the ground, for they worked without any skill, with weak plows and awkward hoes. They were just as badly off as the people of Portugal and Spain at our own day, who are miserably poor, *because* they have bad machines; or as the Chinese laborers, who have scarcely any machines, and are the poorest in the world. There was plenty of labor to be performed, but the tools were so bad, and the want of agricultural knowledge so universal, that the land was never half cultivated, and therefore all classes were poorly off. They had little corn to exchange for manufactures, and in consequence the laborer was badly clothed, badly lodged, and had a very indifferent share of the scanty crop which he raised. In the natural course of things, a good deal of land was laid down to grass; this was superseding labor to a great extent, and much clamor was raised about this plan,

and probably a good deal of real distress was produced. But mark the consequence. Although the money wages of labor were lowered, because there were more laborers in the market, the real amount of wages was higher, for better food was created by pasturage at a cheap rate. The laborer then got meat who had never tasted it before; and when the use of animal food became general, there were cattle and corn enough to be exchanged for manufactured goods, and the laborer got a coat and a pair of shoes, who had formerly gone half naked.*

A very accurate French writer, M. Dupin, in a book lately published, in which he enters into many comparisons between the condition of the people of England and that of the people of France, says, that two-thirds of the French people are at this day wholly deprived of the nourishment of animal food, and that they live wholly on chestnuts, or maize, or potatoes. He accounts for this by stating that in France only 7½ parts in 100 of the soil are cultivated in meadows, while in England, one-third of the whole country is in meadow, or 33 parts in 100. He says, therefore, that the inhabitants of England consume three times as much meat, milk, butter, and cheese, as the inhabitants of France; and that the people of England are consequently three times better furnished with good food. This Frenchman, who writes with an earnest desire to better the condition of his countrymen, exhorts them to improve the breed

* See Appendix, No. III. p. 207.

of cattle, and to lay down more land to grass, that the people may be better nourished. If he thought that more labour, without increased production, would better the people, he would exhort them to break up the 7½ parts in 100 of grass land, and go to work in raising more corn and more potatoes. He does no such thing. He knows that to lessen the price by increasing the quantity of animal food, or of any other comfort, is really to better the condition of the people, by really raising the wages of labor.*

But to return to our triumphant machine-breakers, who utterly despise such considerations. As the year advanced, and the harvest approached, it would be discovered that not one-tenth of the land was sown; for although the plows were gone, because the horses were turned out to starve, and there was plenty of *labor* for those who chose to labor for its own sake, or at the price of a horse, this amazing employment for human hands, somehow or other, would not quite answer the purpose. It has been calculated that the power of horses, oxen, &c. employed in husbandry in Great Britain is ten times the amount of human power. If the human power insisted upon doing all the work with the worst tools, the certainty is that not even one-tenth of the land could be cultivated. Where, then, would all this madness end? In the starvation of the laborers themselves. The people in the towns would probably use *their* machines,

* See Appendix, No IV page 208.

which are ships, and barges, and wagons, to bring them as much of the produce of foreign countries as they could get (and that would be little) in exchange for their manufactures; and the agricultural laborers, who had put themselves out of the sympathy and protection of society, if they were allowed to eat up all they had produced by such imperfect means, would be in an infinitely more wretched state than they could possibly be, if the demand for labor was many times less than it now is. They would be just in the condition of any other barbarous people, that were ignorant of the inventions that constitute the power of civilization. They would eat up the little corn which they raised themselves; and have nothing to give in exchange, for clothes, and coals, and candles, and soap, and tea, and sugar, and all the many comforts which those who are even the worst off are not wholly deprived of.

All this may appear as an extreme statement; and certainly we believe that no such evils could happen: for if the laws were passive, *which they will not be*, the most ignorant of the laborers themselves would, if they proceeded to carry their own principle much farther than they have done, see in their very excesses the real character of the folly and wickedness to which it has led, and would lead them. Why should the laborers of Aylesbury not destroy the harrows as well as the drills? Why leave a machine which separates the clods of the earth, and break one which puts seeds into it? Why deliberate about

a horse-churn, when they are resolved against a winnowing machine? The truth is, these poor men perceive, even in the midst of their excesses, the gross deception of the reasons which induce them to commit them. Their motive is a natural, and if lawfully expressed, a proper impatience, under a condition which has certainly many hardships, and those hardships in great part produced by the want of profitable labor. But in imputing those hardships to machinery, they are at once embarrassed when they come to draw distinctions between one sort of machine and another. This embarrassment decidedly shows that there are fearful mistakes at the bottom of their furious hostility to machinery. Some of these mistakes it is the object of this little book to clear up. We apply ourselves to the task with a confident hope of doing good, because in this very embarrassment we perceive the working of a conscientious principle. There is much ignorance to be encountered; but there is a disposition for honest inquiry, which will, in time, produce the best effects.

CHAPTER III.

It has been said by persons whose opinions are worthy attention, that spade-husbandry is, in some cases, better than plow-husbandry; —that is, that the earth, under particular circumstances of soil and situation, may be more fitly prepared for the influences of the atmo-

sphere, by digging, than by plowing. It is not our business to enter into a consideration of this question. The growth of corn is a manufacture, in which man employs the chemical properties of the soil and of the air, in conjunction with his own labor, aided by certain tools or machines, for the production of a crop; and that power, whether of chemistry or machinery,—whether of the salt, or the chalk, or the dung which he puts upon the earth, or the spade or the plow which he puts into it,—that power which does the work easiest is necessarily the best, *because it diminishes the cost of production.* If the plow does not do the work so well as the spade, it is a less perfect machine; but the less perfect machine may be preferred to the more perfect, because, taking other conditions into consideration, it is a cheaper machine. If the spade, applied in a peculiar manner by the strength and judgment of the man using it, more completely turns up the soil, breaks the clods, and removes the weeds, than the plow, which receives one uniform direction from man with the assistance of other animal power, then the spade is a more perfect machine in its combination with human labor, than the plow is, worked with a lesser degree of the same combination. But still it may be a machine which cannot be used with advantage to the producer, and is therefore not desirable for the consumer. All such questions must be determined by the cost of production; and that cost in agriculture is made up of the rent of land, the profit of capital, and the

wages of labor—or the portions of the produce belonging to the landlord, the farmer, and the laborer. Where rent is high, as in the immediate neighborhood of large towns, it is important to have the labor performed as carefully as possible. It is then economy to turn the soil to the greatest account, and the land is cultivated as a garden. Where rent is low, it is important to have the labor performed with less care, because one acre cultivated by hand may cost more than two cultivated by the plow. It is then economy to save in the labor, and the land is cultivated as a field. In one case, the machine called a spade is used; in the other, the machine called a plow is employed. The use of the one or the other belongs to practical agriculture, and is a question only of relative cost.

And this brings us to the great *principle* of all machinery. A tool of the simplest construction is a machine; a machine of the most curious construction is only a complicated tool. There are many cases in the arts, and there may be cases in agriculture, in which the human arm and hand, with or without a tool, may do work that no machine can so well perform. There are processes in polishing, and there is a process in copper-plate printing, in which no substance has been found to stand in the place of the human hand. And if, therefore, the man with a spade alone does a certain agricultural work more completely than a man guiding a plow, and a team of horses dragging it, (which we do not affirm or deny,) the only reason for

this is, that the man with the spade is a better machine than the man with the plow and the horses. The most stupid man that ever existed is, beyond all comparison, a machine more cunningly made by the hands of his Creator, more perfect in all his several parts, and with all his parts more exquisitely adapted to the regulated movement of the whole body, less liable to accidents, and less injured by wear and tear, than the most beautiful machine that ever was, or ever will be, invented. There is no possibility of supplying in many cases a substitute for the simplest movements of man's body, by the most complicated movements of the most ingenious machinery. And why so? Because the natural machinery by which a man even lifts his hand to his head is at once so complex and so simple, so apparently easy and yet so entirely dependent upon the right adjustment of a great many contrary forces, that no automaton, or machine imitating the actions of man, could ever be made to effect this seemingly simple motion, without showing that the contrivance was imperfect,—that it was a mere imitation, and a very clumsy one. What an easy thing it appears to be for a farming-man to thrash his corn with a flail; and yet what an expensive arrangement of wheels is necessary to produce the same effects with a thrashing machine. The truth is, that the man's arm and the flail form a much more curious machine, than the other machine of wheels, which does the same work; and the real question as regards the value of the two

machines is, which machine in the greater degree lessens the cost of production?

We state this principle broadly, in our examination into the value of machinery in diminishing the cost of producing human food. A machine is not perfect, because it is made of wheels or cylinders, employs the power of the screw or the lever, is driven by wind, or water, or steam, but because it best assists the labor of man, by calling into action some power which he does not possess in himself. If we could imagine a man entirely dispossessed of this power, we should see the feeblest of animal beings. He has no tools which are a part of himself, to build houses like the beaver, or cells like the bee. He has not even learnt from nature to build, instinctively, by certain and unchangeable rules. His power is in his mind; and that mind teaches him to subject all the physical world to his dominion, by availing himself of the forces which nature has spread around him. To act upon material objects he arms his weakness with tools and with machines. As we have before said, tools and machines are in principle the same. When we strike a nail upon the head with a hammer, we avail ourselves of a power which we find in nature—the effect produced by the concussion of two bodies; when we employ a water-wheel to beat out a lump of iron with a much larger hammer, we still avail ourselves of the same power. There is no difference in the nature of the instruments, although we call the one a tool, and the other

a machine. Neither the tool nor the machine have any force of themselves. In one case the force is in the arm, in the other in the weight of water which turns the wheel.

The chief distinction between man in a rude, and man in a civilized state of society is, that the one wastes his force, whether natural or acquired,—the other economizes, that is, saves it. The man in a rude state has very rude instruments; he therefore wastes his force: the man in a civilized state has very perfect ones; he therefore economizes it. Would you not laugh at the gardener who went to hoe his potatoes with a stick, having a short crook at the end? It would be a tool, you would say, fit only for children to use. Yet such a tool was doubtless employed by some very ancient nations; for there is an old medal of Syracuse which represents this very tool. The common hoe of the English gardener is a much more perfect tool, because it saves labor. Could you have any doubt of the madness of the man who would propose that all iron hoes should be abolished, to furnish more extensive employ to laborers who should be provided only with a crooked stick cut out of a hedge? The truth is, if you, the working-men of England, had no better tools than crooked sticks, you would be in a state of actual starvation. One of the chiefs of the people of New-Zealand, who, from their intercourse with Englishmen had learnt the value of tools, told Mr. Marsden, a missionary,

that his wooden spades were all broken, and he had not an ax to make any more;—his canoes were all broken, and he had not a nail or a gimlet to mend them with;—his potato grounds were uncultivated, and he had not a hoe to break them up with;—and that *for want of cultivation* he and his people would have nothing to eat. This shows you the state of a people without tools.

But you would perhaps take a distinction, which we have endeavored to show you is a worthless one, between tools and machines. There are many who object to machinery, because, having grown up surrounded with the benefits it has conferred upon them, without understanding the source of these benefits, they are something like the child who sees nothing but evil in a rainy day. We have mentioned the people of New-Zealand; who live exactly on the other side of the globe, and who, therefore, very rarely come to us; but when they do come they are acute enough to perceive the advantages which machinery has conferred upon us, and the great distance in point of comfort between their state and ours, principally for the reason that they have no machinery, while we have a great deal. One of these poor men burst into tears when he saw a rope-walk; because he perceived the immense superiority which the process of spinning ropes gave us over his own countrymen. Another of these people, and he was a very shrewd and intelligent person, carried back to

his country a small hand-mill for grinding corn, which he prized as the greatest of all earthly possessions.

And well might he prize it! He had no machine for converting corn into meal, but two stones, such as were used in the remote parts of the highlands of Scotland, some years ago. And to beat the grain into meal by these two stones (a machine, remember, however imperfect) would occupy the labor of one-fourth of his family, to procure subsistence for the other three-fourths. The ancient Greeks, three thousand years ago, had improved upon the machinery of the hand-stones, for they had hand-mills. But Homer, the old Greek poet, describes the unhappy condition of the slave who was always employed in using this mill. The groans of the slave were unheeded by those who consumed the produce of his labor; and such was the necessity for meal, that the women were compelled to turn these mills when there were not slaves enough taken in war to perform this irksome office. There was plenty of labor then to be performed, even with the machinery of the hand-mill; but the slaves and the women did not consider that labor was a good in itself, and therefore they bitterly groaned under it. By and by, the understanding of men found out that water and wind would do the same work that the slaves and the women had done; and that a large quantity of labor was at liberty to be employed for other purposes. You perhaps think that society was in a worse state in con-

sequence. We will tell you exactly in what respects society gains, and what you gain as part of society, by the abolition of hand-mills, and the use of wind-mills and water-mills for grinding corn.

Labor is worth nothing without results. Its value is only to be measured by what it produces. If in a country where hand-mills could be had, the people were to go on beating grain between two stones, you would pronounce them fools, because they could obtain an equal quantity of meal with a much less expenditure of labor. You have perhaps a general prejudice against that sort of machinery which does its work with very little human assistance; it is not quite so certain, therefore, that you would agree that a people would be equal fools to use the hand-mill when they could employ the wind-mill or the water-mill. But we believe you would think, that if flour could drop from heaven, or be had like water by whoever chose to seek it, it would be the height of folly to have stones, or hand-mills, or water-mills, or wind-mills, or any machine whatever for manufacturing flour. Do you ever think of *manufacturing* water? The cost of water is only the cost of the labor which brings it to the place in which it is consumed. Yet this admission overturns all your objections against machinery. *You admit that it is desirable to obtain a thing with no labor at all; can you therefore doubt that it is desirable to obtain it with the least possible labor?* The only difference between no labor and a little labor,

is the difference of the cost of production. And the only difference between little labor and much labor is precisely the same. In procuring any thing that administers to his necessities, man makes an exchange of his labor for the thing produced, and the less he gives of his labor the better, of course, is his bargain.

To return to the hand-mill and the water-mill. An ordinary water-mill for grinding corn will grind about thirty-six sacks a day. To do the same work with a hand-mill would require 150 men. At two shillings a day the wages of these men would amount to 15*l.* which, reckoning six working days, is 90*l.* a week, or 4680*l.* a year. The rent and taxes of a mill would be about 150*l.* a year, or ten shillings a working day. The cost of machinery would be certainly more for the hand-mills than the water-mill, therefore we will not take the cost of machinery into the calculation. To produce, therefore, thirty-six sacks of flour by hand we should pay 15*l.*; by the water-mill we should pay ten shillings: that is, we should pay thirty times as much by the one process as by the other. The actual saving is something about one half of the price of the flour in the market; that is, the consumer, if the corn were ground by hand, would pay double what he pays now that it is ground at a mill. He pays 10*d.* for his quartern loaf now; he would pay 20*d.* then.

But if the system of grinding corn by hand were a very recent system of society, and the

introduction of so great a benefit as the water-mill had all at once displaced the hand-grinders, as the spinning machinery displaced the spinning-wheel, what must become, you say, of the one hundred and fifty men who earned the 15*l.* a day, of which sum the consumer has now got 14*l.* 10*s.* in his pocket? They must go to other work. And what is to set them to that work? The same 14*l.* 10*s.*: which, being saved in the price of flour, gives the poor man, as well as the rich man, more animal food and fuel; a greater quantity of clothes, and of a better quality; better furniture, and more of it; domestic utensils, and books. To produce these things there must be more laborers employed than before. The quantity of labor is, therefore, not diminished, while its productiveness is much increased. It is as if every man among us had become suddenly much stronger and more industrious. The machines labor for us, and are yet satisfied without either food or clothing. They increase all our comforts, and they consume none themselves. The hand-mills are not grinding, it is true: but the ships are sailing that bring us foreign produce; the looms are moving that give us more clothes; the potter, and glass-maker, and joiner, are each employed to add to our household goods: we are each of us elevated in the scale of society: and all these things happen because machinery has diminished the cost of production.

CHAPTER IV.

All laborers in agriculture know full well the value of a tool; but some hate machinery. This is inconsistent. Unless the laborer made a plow (if he will consent even to a plow) out of two pieces of stick, and carried it upon his shoulder to the field, as the toil-worn and poor people of India do, he must have some *iron* about it. He cannot get iron without machinery. He hates machinery, and therefore he will have nothing to do with a plow! Will he have his hoe, then? He is not quite sure. Will he give up his knife? No; he must keep his knife. He has got every thing to do for himself, and his knife is his tool of all-work.

Well, how does he get this same knife? People that have no machinery sharpen a stone, or bit of shell, or bone, and cut or saw with it in the best way they can; and after they have become very clever, they fasten it to a wooden handle with a cord of bark. An Englishman examines two or three dozens of knives, selects which he thinks the best, and pays a shilling for it, the seller thanking him for his custom. The man who has nothing but the bone or the shell would gladly toil a month, for that which does not cost an English laborer half a day's wages.

And how does the Englishman obtain his knife upon such easy terms? From the very

same causes that he obtains all his other accommodations cheaper, in comparison with the ordinary wages of labor, than the inhabitant of any other country,—that is, from the use of machinery, either in the making of the thing itself, or in procuring that without which it could not be made. We must always remember that if we could not get the materials without machinery, it would be as impossible for us to get what is made of those materials as if a machine delivered it to us ready for use.

Keeping this in mind, let us see how a knife could be obtained by a man who had nothing to depend upon but his hands.

Ready-made, without the labor of some other man, a knife does not exist; but the iron, of which the knife is made, is to be had. Very little iron has ever been found in a native state, or fit for the blacksmith. The little that has been found in that state has been found only very lately; and if human art had not been able to procure any in addition to that, gold would have been cheap as compared with iron.

Iron is, no doubt, very abundant in nature; but it is always mixed with some other substance that not only renders it unfit for use, but hides its qualities. It is found in the state of what is called *iron stone*, or *iron ore*. Sometimes it is mixed with clay, at other times with lime or with the earth of flint; and there are also cases in which it is mixed with sulphur. In short, in the state in which iron is frequently met with, it is a much more likely

substance to be chosen for paving a road, or building a wall, than for making a knife.

But suppose that the man knows the particular ore or stone that contains the iron, how is he to get it out? Mere force will not do; for the iron and the clay, or other substance, are so nicely mixed, that though the ore were ground to the finest powder, the grinder is no nearer the iron than when he had a lump of a ton weight.

A man who has a block of wood has a wooden bowl in the heart of it; and he can get it out too by labor. The knife will do it for him in time; and if he take it to the turner, the turner, with his machinery, his lathe, and his gouge, will work it out for him in half an hour. The man who has a lump of iron ore has just as certainly a knife in the heart of it; but no mere labor can work it out. Shape it as you may, it is not a knife, or steel, or even iron,—it is iron ore; and dress it as you will, it would not cut better than a brick-bat,—certainly not so well as the shell or bone of the savage.

There must be knowledge before any thing can be done in this case. We must know what is mixed with the iron, and how to separate it. We cannot do it by mere labor, as we can chip away the wood and get out the bowl; and therefore we have recourse to fire.

In the ordinary mode of using it, fire would make matters worse. If we put the material into the fire as a stone, we should probably receive it back as slag or dross. We

must, therefore, prepare our fuel. Our fire must be hot, very hot; but if our fuel be wood we must burn it into charcoal, or if it be coal into coke.

The charcoal, or coke, answers for one purpose; but we have still the clay or other earth mixed with our iron, and how are we to get rid of that? Pure clay, or pure lime, or pure earth of flint, remains stubborn in our hottest fires; but when they are mixed in a proper proportion, the one melts the other.

So charcoal or coke, and iron stone or iron ore, and limestone, are put into a furnace; the charcoal, or coke, is lighted at the bottom, and wind is blown into the furnace, at the bottom also. If that wind is not sent in by machinery, and very powerful machinery too, the effect will be little, and the work of the man great; but still it can be done.

In this furnace the lime and clay, or earth of flint, unite, and form a sort of glass, which floats upon the surface. At the same time the carbon, or pure charcoal, of the fuel, with the assistance of the limestone mixes with the stone, or ore, and melts the iron, which, being heavier than the other matters, runs down to the bottom of the furnace, and remains there till the workman lets it out by a hole made at the bottom of the furnace for that purpose, and plugged with sand. When the workman knows there is enough melted, or when the appointed time arrives, he displaces the plug of sand with an iron rod, and the melted iron runs out like water, and is conveyed into fur-

rows made in sand, where it cools, and the pieces formed in the principal furrows are called "sows," and those in the furrows branching from them, "pigs." A single furnace will, in this way, make seventy-five tons of iron in a week; or as much iron in the year as will make the blades of about one hundred and forty millions of knives, at an ounce to each blade.

But great as is the advantage of this first step of the iron-making, the iron is not yet fit for a knife. It is cast-iron. It cannot be worked by the hammer, or sharpened to a cutting edge; and so it must be made into malleable iron,—into a kind of iron which, instead of melting in the fire, will soften, and admit of being hammered into shape, or united by the process of welding.

The methods by which this is accomplished vary; but they in general consist in keeping the iron melted in the furnace, and stirring it with an iron rake, till the blast of air in the furnace burns the greater part of the carbon out of it. By this means it becomes tough; and, without cooling, is taken from the furnace and repeatedly beaten by large hammers, or squeezed through large rollers, until it becomes the bar-iron of which so much use is made in every art of life.

Bringing it into this state requires great force; and the unaided strength of all the men in Britain could not make all the iron which is at present made, though they did nothing else. Machinery is therefore resorted to;

and water-wheels, steam-engines, and all sorts of powers are set to work in moving hammers, turning rollers, and drawing rods and wires through holes, till every workman can have the particular form which he wants. If it were not for the machinery that is employed in the manufacture, no man could obtain a spade for less than the price of a year's labor; the yokes of a horse would cost more than the horse himself; and the farmer would have to return to wooden plow-shares, and hoes made of sticks with crooked ends. There would be *labor* enough then, as we have already shown:—but the people could not live upon the labor only; they must have *profitable* labor.

After all this, the iron is not yet fit for a knife, at least for such a knife as an Englishman may buy for a shilling. Many nations would, however, be thankful for a little bit of it, and nations too in whose countries there is no want of iron ore. But they have no knowledge of the method of making iron, and have no furnaces or machinery. When our ships sail among the people of the eastern islands, those people do not ask for gold. "Iron, iron!" is the call; and he who can exchange his best commodity for a rusty nail or a bit of iron hoop is a fortunate individual.

We are not satisfied with that in the best form, which is a treasure to those people in the worst. We must have a knife, not of iron, but of *steel*,—a substance that will bear a keen edge without either breaking or bending. In

order to get that, we must again change the nature of our material.

How is that to be done? The oftener that iron is heated and hammered, it becomes the softer and more ductile; and as the heating and hammering forced the carbon out of it, if we give it the carbon back again, we shall harden it; but it happens that we also give it other properties. by restoring its carbon, when the iron has once been in a ductile state.

For this purpose, bars or pieces of iron are buried in powdered charcoal, covered up in a vessel, and kept at a red heat for a greater or less number of hours, according to the object desired. There are niceties in the process, which it is not necessary to explain, that produce the peculiar quality of steel, as distinguished from cast-iron. If the operation of heating the iron in charcoal is continued too long, or the heat is too great, the iron becomes cast-steel, and cannot be welded; but if it is not melted in the operation, it can be worked with the hammer in the same manner as iron.

In each case, however, it has acquired the property upon which the keenness of the knife depends; and the chief difference between the cast steel and the steel that can bear to be hammered is, that cast steel takes a keener edge, but is more easily broken.

The property which it has acquired is that of bearing to be tempered. If it be made very hot, and plunged into cold water, and kept there till it is quite cooled, it is so hard

that it will cut iron, but it is brittle. In this state, the workman brightens the surface, and lays the steel upon a piece of hot iron, and holds it to the fire till it becomes of a color which he knows from experience is a test of the proper state of the process. Then he plunges it again into water, and it has the degree of hardness that he wants.

The grinding a knife, and the polishing it, even when it has acquired the requisite properties of steel, if they were not done by machinery, would cost more than the whole price of a knife upon which machinery is used. A travelling knife-grinder, with his treadle and wheels, has a machine, but not a very perfect one. The Sheffield knife-maker grinds the knife at first upon wheels of immense size, turned by water or steam, and moving so quickly, that they appear to stand still—the eye cannot follow the motion. With these aids the original grinding and polishing cost scarcely any thing; while the travelling knife-grinder charges two-pence for the labor of himself and his wheel, in just sharpening it.

As iron is with us almost as plentiful as stone, we do not think much about it. But there is a great deal to be done, much thinking and inventing, before so simple a thing as a shilling knife could be procured: and without the thinking and the inventing, all the strength of all the men that ever lived never could procure it; and without the machinery to lighten the labor, no ingenuity could furnish it at a thousand times the expense.

And why then can an ordinary workman procure it for the price of a few hours' labor? The causes are easily seen. Every part of the labor that can be done by machinery is so done. One turn of a wheel, one stroke of a steam-engine, one pinch of a pair of rollers, or one blow of a die, will do more in a second than a man could do in a month. Another advantage in the manufacture is, that the labor is divided. Each man has but one thing to do, and in course of time he comes to do twenty times as much as if he were constantly shifting from one thing to another. The value of the work that a man does is not to be measured in all cases by the time and trouble that it costs him individually, but by the market value of what he produces; which value is determined, as far as labor is concerned, by the price paid for doing it in the best and most expeditious mode. He that fells a sapling by one stroke of his ax, does just as much work as he that should take a week to rip it asunder with his nails, or gnaw it with his teeth, according to Joseph Foster's expression.

And does not all this machinery, you still say, deprive many workmen of employment? No. By these means the iron trade gives bread to hundreds, where otherwise it would not have given bread to one. There are more hands employed at the iron-works than there would have been if there had been no machinery; because without machinery men could not produce iron cheap enough to be generally used.

Then the number of founders and smiths!

The pans and kettles, the pipes, the grates, the thousands of iron things that we see, all employ somebody; and every body is benefited by the use of them. We make bridges of iron, roads of iron, wagons of iron, boats of iron, steam-engines of iron; and, in fact, so many things of iron, that if we were deprived of it, our country would not be worth inhabiting. As many iron pipes have been laid down for supplying water and light to the inhabitants of London alone, within the last twenty years, as, without machinery, would have kept all the world busy for a century, or rather, could not have been procured at all. You will have more facts on this branch of the subject, in a succeeding chapter.

Then there are the tools of every trade. All the working parts of them are made of iron, and very many of them are made of iron altogether. How could the hedger proceed without his bill, or the ditcher without his mattock? The first could not do with wood at all, and the last would made but sorry work. Then come the spade, the hoe, the scythe, and the sickle. How could they be had without iron? or what would be the condition of the laborer, if iron and iron tools were sold at the price of making them without machinery? His tools now cost him only the produce of a few days of his own labor;—in many cases they are supplied to him. If they were made by hand, they would cost him the labor of many weeks to purchase them, if they could be purchased at all. His tools are, however, a first necessary of life to

the laborer;—he cannot earn his bread without them. If he bought the tools at the dear rate, he would probably spend half his earnings in buying them; and then he must be paid double.

But instead of there being any thing to pay double wages to the labourer, every body would be in the same necessity as himself; and the necessity would be that he and they would either pay double for all that was bought, or work for half-price. The ax, the saw, the plane, the gimlet, and the nails, would consume all the earnings of the carpenter; the needles, the shears, and the goose, would be a burden to the tailor; the farmer would be obliged to pay in the additional price of iron what he now pays to his laborers; and labor itself would be at an end.

There was a time when iron was made in this country with very little machinery. Iron was manufactured here in the time of the Romans; but it was made with great manual labor, and was consequently very dear. Hutton, in his History of Birmingham, tells us that there is a large heap of cinders near that town which have been produced by an ancient iron furnace; and that from the quantity of cinders, as compared with the mechanical powers possessed by our forefathers, the furnace must have been constantly at work from the time of Julius Cæsar. A furnace with a steam blast would produce as large a heap in a few years. It is always a difficulty at the iron-works to get rid of their cinders.

The machinery that is now employed in the iron trade, not only enables the people to be supplied cheaply with all sorts of articles of iron, but it enables a great number of people to find employment, not in the iron trade only, but in all other trades, who otherwise could not have been employed; and it enables everybody to do more work with the same exertion by giving them better tools; while it makes all more comfortable by furnishing them with more commodious domestic utensils.

There are thousands of families on the face of the earth, that would be glad to exchange all they have for a tin kettle, or an iron pot, which can be bought anywhere in the three kingdoms for eighteen pence. And could the poor man in this country but once see how even the rich man in some other places must toil day after day before he can scrape or grind a stone so as to be able to boil a little water in it, or make it serve for a lamp, he would account himself a poor man no more. An English gipsy carries about with him more of the conveniences of life than are enjoyed by the chiefs or rulers in countries which naturally have much finer climates than that of England. But they have no machinery, and therefore they are wretched.

One or two facts will show still more forcibly the value of machinery in the iron-works. In 1788, the whole iron made in the year did not amount to seventy thousand tons; and seventy thousand tons more were imported in bars from Sweden and Russia, which must have

been paid for out of the labor of the people in England. At present the quantity annually made in Britain is not less than six hundred thousand tons. The quantity made yearly has increased nearly nine-fold in the space of less than half a century.

Nearly all the people now engaged in iron-works are supported by the improvements that have been made in it *by machinery* since 1788. Yes, wholly by the machinery; for before then the quantity made by the charcoal of wood had fallen off one-fourth in forty-five years. The wood for charcoal was becoming exhausted, and nothing but the powerful blast of a machine will make iron with coke. Without the aid of machinery the trade would have become extinct. The iron and the coal employed in making it would have remained useless in the mines.

CHAPTER V.

We have seen what an important article *coal* is in the manufacture of iron. It is so important, that iron-works in England are invariably carried on in the coal counties. In France there are nearly four hundred charcoal furnaces; but they do not do more than a fourth of the work of smelting iron which is done by our coke furnaces, of which, in England and Wales, there are about three hundred, each producing, when in full work, upon the

average, fifty tons a week, or the enormous quantity of seven hundred and eighty thousand tons a year.

In every part of the operation of making iron;—in smelting the iron out of the ore; in moulding cast-iron into those articles for which it is best adapted; in working malleable iron and steel, and in applying them to use after they are made; nothing can be done without fire, and the fuel that is used in almost every stage of the business is coal. The coal trade and the iron trade are thus so intimately connected, so very much dependent upon each other, that neither of them could be carried on to any extent without the other. The coal mines supply fuel, and the iron-works give mining tools, pumps, rail-roads, wheels, and steam-engines in return. A little coal might be got without the iron engines, and a little iron might be made without coals, by the charcoal of wood. But the quantity of both would be trifling in comparison. Thus it is, that to make six hundred thousand tons of iron, requires five times the quantity, or, three million tons, of coal. This large quantity is only for the production of pig-metal. In other castings, and in the various subsequent stages of iron manufacture, many more tons of coal are employed.

Through the general consumption of wood instead of coal, a fire for domestic use in France is a great deal dearer than a fire in England; because, although the coal-pits are not to be found at every man's door, nor within many

miles of the doors of some men, machinery at the pits, and ships and barges, which are also machinery, enable most men to enjoy the blessings of a coal fire at a much cheaper rate than a fire of wood, which is not limited in its growth to any particular district. Without the machinery to bring coals to his door, one man out of fifty of the present population of England could not have had the power of warming himself in winter; any more than without the machines and implements of farming he could obtain food, or without those of the arts he could procure clothing. The sufferings produced by a want of fuel cannot be estimated by those who have abundance. In Normandy, at the present day, such is the scarcity of wood, that persons engaged in various works of hand, as lace-making by the pillow, absolutely sit up through the winter nights in the barns of the farmers, where cattle are littered down, that they may be kept warm by the animal heat which is around them. They sleep in the day, and are warmed by being in the same out-house, with cows and horses at night;—and thus they work under every disadvantage, because fuel is scarce and very dear.

Well, suppose that our machinery (not mere tools, but more complicated instruments) were laid aside, and all the works and contrivances that have been made by means of it put an end to, and the people left to find coals with shovels and pickaxes, and all the tools used in common digging. How would they go about

this task, or what would the coals cost as compared with the present price?

At present a cottager in the south of England, where there is no coal in the earth, may have a bushel of good coals delivered at the door of his cottage for eighteen pence. If he had even the means of transporting himself and his family to the coal district, he could not, without machinery, get a bushel of coals at the price of a year's work. Let us see how a resolute man would proceed in such an undertaking.

The machinery, we will say, is gone. The mines are filled up, which the greater part of them would be, with water, if the machinery were to stop a single week. Let us suppose that the adventurous laborer knows exactly the spot where the coal is to be found. This knowledge in a country that has never been searched for coals before, is no easy matter even to those who understand the subject best; but we shall suppose that he gets over that difficulty too, for after it there is plenty of difficulty before him.

Well, he comes to the exact spot that he seeks, and places himself right over the seam of coal. That seam is only a hundred fathoms below the surface, which depth he will, of course, reach in good time. To work he goes; pares off the green sod with his shovel, loosens the earth with his pickax, and, in the course of a week, is twenty feet down into the loose earth and gravel, and clears the rock at the bottom. He rests during the Sunday, and comes re-

freshed to his work on Monday morning; when, behold, there are twelve feet of water in his pit!

Somebody now lends him a bucket and rope, (a machine, mind,) and he bales away, till, as night closes, he has lowered the water three feet. Next morning it is up a foot and a half: but no matter; he has done something, and next day he redoubles his efforts and brings the water down to only four feet. That is encouraging; but, from the depth, he now works his bucket with more difficulty, and it is again a week before his pit is dry. The weather changes; the rain comes down heavily; the surface on which it falls is spongy; the rock which he has reached is water-tight; and in twelve hours his pit is filled to the brim. It is in vain to go on.

But suppose the man, in spite of every difficulty, to reach the coal at last, which he might do possibly at the end of twelve months. If he is wise he will even then desist, and return to his family, whom somebody must have supported while he was making these fruitless exertions, satisfied that it is better to spend a day's wages in the purchase of a bushel of coals, than to waste weeks, and months, and years in an attempt to get it, without absolute payment, but at a sacrifice of labor which under the most favorable circumstances would add a hundred fold to the market price.

The sinking of a pit, even to a less depth than a hundred fathoms, sometimes demands, notwithstanding all the improvements by

machinery, a sum of not less than a hundred pounds a fathom, or ten thousand pounds for the whole pit; and therefore, supposing it possible for a single man to do it at the rate of eighteen pence a day, the time which he would require would be between four hundred and five hundred years.

Whence comes it that the labor of between four hundred and five hundred years is reduced to a single day, and that which, independently of the carriage, would have cost ten thousand pounds, is got for eighteen pence? It is because man joins with man, and machinery is employed to do the drudgery. Nations that have no machinery have no coal fires, and are ignorant that there is hidden under the earth a substance which contributes more, perhaps, to the health and comfort of the inhabitants of Britain than any other commodity which they enjoy.

Yes, that the coals are procured for so mere a trifle in comparison—that they are procured at all—is owing to every part of the labor that can be so performed being performed by machinery; and that the machinery exists, and this vast addition is made to every man's comfort, is owing to there being men in the country with capital enough to bear the expense, and with spirit enough to risk their property in operations of so much cost and magnitude.

Some of the particulars of the mode in which coals are obtained deserve to be mentioned, for the purpose of showing with what ease machinery can do that which to human

strength, however skilfully applied, if unassisted by machinery, would be utterly impossible.

Suppose the men digging in a narrow pit, such as that which is sunk for the purpose of "winning" coals, how would they, after they had reached a certain depth, raise the earth and rubbish to a surface, and go down or come up? Without machinery there are really no means, but by putting down a ladder, or cutting steps in the side of the pit. With such aids, let us consider how much rubbish a man could bring up in a day. Coulomb, a French mathematician, found that a man without any load could climb up steps to a height of about eighty-two fathoms, eighteen times within the hours of ordinary work. There would be, therefore, at most, only eighteen daily ascents from the pit, even if the man brought nothing with him. If he carry a load, his power of ascent is of course much diminished.

But art performs what merely bodily strength cannot accomplish. When the pit becomes too deep for throwing out the earth with a shovel, a windlass is put across it with a rope and buckets, so that while the full one is drawn up the empty one is let down. One man works the windlass, and another digs.

When the man who digs comes to stone, he lays aside the pickax and the shovel, takes the iron "jumper," drills a hole in the rock, puts in a shot of gunpowder, lays a few fagots over for safety, lights the train, and is drawn some yards up by the bucket. Thunder goes

the shot, the fagots prevent all danger from the fragments, and as much stone is loosened in two minutes as the man would have loosened with his pickax in a week. This is a chemical aid; an aid which is as powerful in diminishing cost of production as the aid of machinery. There is therefore now nothing to do but to fill the buckets, and so another man is sent to the windlass.

When the pit gets still deeper, the windlass is laid aside, and the horse-gin is mounted. According to Smeaton, the power of a horse is equal to five men at the same kind of labor. Other writers estimate the power of a horse at more than six men. One of the three men can attend to the horse and empty the buckets, and the two are at liberty to dig and fill below; so that with the gin and horse, the labor of many men is saved.

The number of men that can work at a windlass, or the number of horses that can be yoked to a gin, is limited. But the power of the steam-engine is limited only by the strength of the materials of which it is formed. The power of a hundred horses, or of five hundred men, may be very easily made by the steam-engine to act constantly, and on a single point; and thus there is scarcely any thing in the way of mere force which the engine cannot be made to do. We have seen a pit in Staffordshire, which hardly gave coal enough to maintain a cottager and his family, for he worked the pit with imperfect machinery; with a half-starved ass applied to a windlass. A mile off was

a steam-engine of 200-horse-power, raising tons of coals and pumping out rivers of water with a force equal to at least a thousand men. This vast force acted upon a point; and therefore no advantage was gained over the machine by the opposing force of water, or the weight of the material to be raised. Before the steam-engine was invented, the produce of the coal-mines barely paid the expense of working and keeping them dry; and had it not been for the steam-engines and other machinery, the supply would long before now have dwindled into a very small quantity, and the price would have become ten or twenty times its present amount.

Engines or machines, of some kind or other, not only keep the pits dry and raise the coals to the surface, but convey them to the ship; and the ship, itself a machine, carries them round all parts of the coast; while barges and boats (still machines) convey them along the rivers and canals. By these means, a ton is carried from the pit to the cottage of the laborer, for less expense than, in the distant places, he himself could fetch a pound, even although he were to get it for nothing at the pit. We shall see, in the next chapter, how all machines which facilitate the general communication between man and man, whether from town to town, from district to district, from county to county, or from nation to nation, advance the general welfare of mankind.

What are the consequences of machinery employed in raising coals? That by machinery many millions of tons of one of the very first

necessaries of life are obtained, which without machinery could not be obtained at all in the thousandth part of the quantity; and which, consequently, would be a thousand times the price—would, in fact, be precious stones, instead of common fuel.

It is estimated that between forty and fifty thousand people are actually employed in the collieries on the Tyne and Wear districts alone, and in the business connected with those collieries. These cannot be above one-third of the whole so employed in the United Kingdom. But when the young, the infirm, and the aged, are taken into consideration, it is not too much to say that for every one that works, two are supported without working. Therefore it is within the mark to say that the coal-trade directly supports one in every forty of all the people of England.

But all these people are not only *employed* in union with the machinery, but they are *more comfortably employed* than they would be without it.

In all mining-operations, conducted as they are in modern times, and in our own country, we must either go without the article produced, whether coal, or iron, or lead, or tin, if the machines were abolished,—or we must employ human labor, in works the most painful, at a price which would not only render existence unbearable, but destroy it altogether. The people, in that case, would be in the condition of the unhappy natives of South America, when the Spaniards resolved

to get gold at any cost of human suffering. The Spaniards had no machines but pickaxes and spades, to put in the hands of the poor Indians. They compelled them to labor incessantly with these, and half the people were destroyed. Without machinery, in places where people can obtain even valuable ore for nothing, the collection and preparation of metals is hardly worth the labor. Mungo Parke describes the sad condition of the Africans who are always washing gold dust;—and we have seen in Derbyshire a poor man separating small particles of lead from the limestone, or spar, of that country, and unable to earn a shilling a day by the process. A man of capital erects lead-works, and in a year or two obtains an adequate profit, and employs many laborers.

The mines of Cornwall, especially those of tin and copper, are of the greatest value; many of them are deep, and contain a great deal of water; and the country produces no coal. The water used to be drawn out of those mines by pumps; and Mr. Davies Gilbert remembers the man who assisted in making the first horse-gin that was seen to the west of St. Michael's mount.

From the joint experiments of Messrs. Watt and Bolton, and the principal miners, the best steam-engines, in 1778, raised two thousand gallons, from a depth of three hundred and forty-eight feet, for every bushel of coal used.

An ordinary man, working with a good

pump, will raise one thousand gallons from the same depth in a day.

In 1829, the best engine in Cornwall, did ten times the work of those in 1778, or each bushel of coal raised twenty thousand gallons of water.

In 1829, therefore, one bushel of coal did the work of twenty men, or of four horses for one whole day.

The rearing of men, or of horses, bears as great a proportion to the whole of their labor, as the cost of steam-engines does to that which they can do.

Therefore, a bushel of coals, by the steam-engine, buys as much labor as the wages of twenty men, or the keep of four horses.

A bushel of coal (which is about three-quarters of a hundred weight, at twenty shillings a ton) costs ninepence in the coal districts; in the places where the price is highest it will not cost more than one shilling and ninepence; and the cost of coal for the whole engines may be therefore taken at the average of fifteen pence.

Therefore, by an engine, the work of twenty men may be got for fifteen pence, while the men, at fifteen pence a day, would cost twenty-four shillings.

Men, therefore, could not compete with steam-engines if they asked more than fourpence halfpenny in the week, or three farthings for each day's hard work of ten hours. If they worked at a rate like this, they would be worse

off than were the Indians of South America. If the men did not work as cheaply as the engines, the coals would not be consumed as extensively as machinery enables them to be consumed. The consumption of coals has increased much more rapidly than the increase of the population. In the time of Charles II. two hundred thousand chaldrons were annually consumed in London. At the present time, above a million and a half chaldrons are consumed. It has been calculated that each person in London, in 1801, used a chaldron of coals in a year, and that now a chaldron and one-sixth is used by each person. The competition of capital, and improved machinery, have made coals cheaper.

CHAPTER VI.

The chief power which produces coal and iron cheap at the pit, is that of machinery. It is the same power which distributes these bulky articles through the country, and equalizes the cost in a great degree to the man who lives in London, and the man who lives in Durham or Staffordshire.

About a hundred and fifty years ago, when the first turnpike-road was formed in England, the mob broke the toll-gates, because they thought an unjust tax was being put upon them. They did not perceive that this small tax, for

the use of a road, would confer upon them innumerable comforts, and double and treble the means of employment.

If there were no road, and no bridge, a man would take six months in finding his way from London to Edinburgh, if indeed he found it at all. He would have to keep the line of the hills, in order that he might come upon the rivers at particular spots, where he would be able to jump over them with ease, or wade through them without danger.

When a man has gone up the bank of a river for twelve miles in one direction, in order to be able to cross it, he may find that before he proceeds one mile in the line of his journey, he has to go back the bank of another river for twelve miles in the opposite direction; and the courses of the rivers may be so crooked that he is really further from his journey's end at night than he was in the morning.

He may come to the side of a lake, and not know the end at which the river, too broad and deep for him to cross, runs out; and he may go twenty miles the wrong way, and thus lose forty.

Difficulties such as these are felt by every traveller in an uncivilized country. In reading books of travels, in Africa for instance, we sometimes wonder how it is that the adventurer proceeds a very few miles each day. We forget that he has no roads.

If the natural obstacles against travelling were not removed by art, it is within the truth to say that any man who had to go from one

end of Britain to the other, would lose six months. If he wished to carry a ton, or even a hundred weight, of any sort of goods with him, he could not perform the journey at all.

The produce of the different parts of the country are different, and the goods, whether manufactured or not, that are to spare at any one place, are wanted at some other. One county produces corn, another coals and plowshares. Both are useless where they are, and the places are miles distant. If a man went with corn for a plowshare, his corn would be eaten before he got half way. There could be no communication.

Pack-horses, fifty years ago, carried on the communication in manufacturing districts, upon roads where no wheel-carriage could proceed; but the intercourse in that way was very expensive, and consequently limited.

Roads and wheel-carriages are the next step. Roads in the straight line, up one hill and down another, as the Romans made them; and roads full of ruts, made of bad materials, and never attended to, add much to the cost of production. As the team draws no more along the whole road than it can draw along the worst part of it, the traffic is small and costly; and doubles the price of an article by the time that it has been carried thirty or forty miles.

This is a great loss to all parties. The sellers sell only half what they could sell, and so they must charge more for it; and the buyers, consequently, obtain a diminished

quantity. Mr. Jacob, who went upon the continent to see what stores of wheat the people had, found that in the sandy roads of parts of Germany and Poland, the original price of wheat was doubled by the price of conveyance, in a very few miles.

It is quite plain that he who finds out the means of conveying persons or goods from one place to another in half the time in which they have been accustomed to be conveyed, does the very same thing as if he brought the places one-half nearer.

On foot a man could carry twenty-eight pounds from London to York in ten days; the mail coach can carry a ton from London to York in twenty-four hours; the distance is 200 miles. York is really, then, for all purposes of trade, brought within half a mile of London by the mail, as compared with the porter on foot. Forty times the weight is carried, and it is carried in one-tenth of the time. The only cost to be subtracted from the gain is the expense of the mail.

It is the rapidity, however, that is the principal value, and not the mere cheapness independent of time; for that which is of the utmost consequence to-morrow, may be of no value whatever ten days hence. The saving of time is the greatest of all savings.

Water is another great mode of communication. A man can move with his finger a log in the water, which all his force could not stir on land. A man can lift a lump of brick with ease, as long as it is completely under water,

although he would be obliged to drop it before he got it altogether out.

The cause is very simple; it sinks down till it is just as heavy as the water, and thus in as far as weight is concerned, the moving of it does not differ from the moving of the water. Brick is exactly double the weight of water; and, therefore, a man can lift two hundred weight in the water with the same exertion of his strength as he lifts one hundred weight in the air.

Thus, if the lump of brick is one hundred weight in the water, it will be one hundred and a half when half way out, and two hundred when out altogether; and if the man cannot lift two hundred weight, he will never be able to bring it quite out of the water, though he may move it about when wholly under water, or when a part only is above.

If the thing, whatever it is, floats, the only labor in drawing it is that of displacing a certain quantity of water.

The communication between distant countries by means of ships is of a paramount necessity; for without them the communication could not exist at all. The ships of England cause employment and a living for many thousands of people, that otherwise could have found none. But they also give us the commodities of all parts of the world at a rate not much higher than is paid by the people of the countries where they are produced, and sometimes even cheaper than in parts of those countries themselves. This extraordinary re-

sult is produced by the circumstance that land-carriage in the interior of a country is dearer than water-carriage from its ports. The writer of this book received lately a package from Havre, a French port; and the cost of bringing it by sea from Havre was less than the cost of bringing it in a cart from the docks at the east-end of London to a house at the west-end. Havre is nearer to London in the price of transport, than the Custom-house of London is to Pall-Mall. We cannot have a more striking proof of the value of ship-machinery, by which we obtain all the commodities which the world produces, in greater abundance and at a cheaper rate than the people of any other country.

In our rivers we have vast quantities of goods moved along by the tide, with little more labor than taking care that the barges do not get aground; and where there is no tide, horses are used on a towing-path. Horses work to a disadvantage there, but still one does the work of a great number employed in land-carriage. On the canals which cross the country in all directions, the effect is still greater; and though the expense of making canals is considerable, they generally yield large profits; while they give employment to ten times as many people as could be employed without them.

The conveyance of goods by canals is cheap; but it is a slow conveyance when compared with that of a coach. We might naturally suppose that the slow motion of canals might

be got the better of by steam-boats, as contrary winds and calms are got the better of in the narrow seas. But that is not the case. The steam-boat produces a great deal of motion in the water, by which the banks of the canal would be injured; and the canal would have to be made extravagantly expensive for the load that the boat, burdened with its machinery, could carry, to prevent mutual injury by the boat striking the banks.

Machinery is not without its resources, for the purpose of combining cheapness and expedition. Machinery gives us the rail-way and the steam-carriage, to the action of which, either in strength or in speed, there is no limit but the strength of the materials. The most complete instance of this means of communication is upon the rail-way between Liverpool and Manchester, and the following is an account of the first conveyance of heavy goods along this rail-way in December, 1830.

The train consisted of eighteen wagons, containing a hundred and thirty-five bags and bales of American cotton, two hundred barrels of flour, sixty-three sacks of oatmeal, and thirty-four sacks of malt, weighing altogether fifty-one tons, eleven hundred weight, and one quarter. To this must be added the weight of the wagons and oil-cloths, viz. twenty-three tons, eight hundred weight, and three quarters; the tender, with water and fuel, four tons; and of fifteen persons on the train, one ton; making a total weight of exactly *eighty tons*, exclusive of the engine,

about six tons. The journey was performed in two hours and fifty-four minutes, including three stoppages of five minutes each (one only being necessary under ordinary circumstances) for oiling, watering, and taking in fuel; under the disadvantages also of an adverse wind, and of a great additional friction in the wheels and axles, owing to their being entirely new. The train was assisted up the Rainhill inclined plane, by other engines, at the rate of nine miles an hour, and descended the Sutton inclined plane at the rate of sixteen miles and a half an hour. The average rate on the other parts of the road was twelve miles and a half an hour, the greatest speed on the level being fifteen miles and a half an hour.

All these modes of communication are nothing but applications of machinery. The road is a sort of machine; the coach and the wagon are machines; the barge, the ship, and the steam-ship are machines; the rail-way and the locomotive engine (or engine moving from place to place) are machines. If these were to be destroyed, all the other advances in civilization that have taken place amongst us would be of comparatively little advantage, as there would be no means of bringing the produce and the consumers together. Without the means of conveying goods to a market, the prices of commodities would be doubled, and many thousands would be thrown out of bread.

CHAPTER VII.

We have endeavored to explain the general principle that easy communications, whether of roads, or canals, or rail-ways, between one part of a country and another, add to the general wealth, and diminish the cost of production. We shall proceed to give some particular examples of the advantages of improved communication to country districts remote from towns, and particularly to the laboring population of those districts.

In England, at the present day, there is no part of the country without good roads. It would be impossible for a traveller in England to set himself down in any situation where the post from London would not reach him in three days. Fifty years ago such a quickness of communication would have been considered beyond the compass of human means. It would be easy to show what benefits have been conferred upon the poorest inhabitant of England, by the roads and canals which now intersect the country in every direction. But the value of these blessings may be better estimated, by viewing the condition of such parts of the United Kingdom as are just beginning to enjoy them.*

In the Highlands of Scotland, at the begin-

* See Appendix, No. II. p. 213.

ning of the present century, the communication from one district to another was attended with such difficulty and danger, that some of the counties were excused from sending jurors to the circuit to assist in the administration of justice. The poor people inhabiting these districts were almost entirely cut off from intercourse with the rest of mankind. The Highlands were of less advantage to the British empire than the most distant colony. Parliament resolved to remedy the evil; and, accordingly, from 1802 to 1817, the sum of two hundred thousand pounds was laid out, in making roads and bridges in these mountainous districts. Mark the important consequences to the people of the Highlands, as described by Mr. Telford, the engineer of the roads.—

"In these works, and in the Caledonian canal, about three thousand two hundred men have been annually employed. At first they could scarcely work at all; they were totally unacquainted with labor, they could not use the tools; but they have since become excellent laborers; of that number we consider one-fourth left us annually, taught to work. These works may be considered in the light of a working academy, from which eight hundred have annually departed improved workmen. These men have either returned to their native districts, having had the experience of using the most perfect sorts of tools and utensils, (which alone cannot be considered as less than ten per cent. on any

labor,) or they have been usefully disseminated throughout the other parts of the country. Since these roads were made accessible, wheelwrights and cartwrights have been established, the plow has been introduced, and improved tools and utensils are used. The plow was not previously used in general; in the interior and mountainous parts they frequently used crooked sticks with iron on them, drawn or pushed along. The moral habits of the great mass of the working classes are changed; they see that they may depend on their own exertions for support; this goes on silently, and is scarcely perceived until apparent by the results. I consider these improvements one of the greatest blessings ever conferred upon any country. About two hundred thousand pounds have been granted in fifteen years. It has been the means of advancing the country at least one hundred years."

There are many parts of Ireland which sustain the same miseries and inconveniences from the want of roads, as the Highlands of Scotland did at the beginning of the present century. In 1823, Mr. Nimmo, the engineer, stated to parliament, that the fertile plains of Limerick, Cork, and Kerry, were separated from each other by a deserted country, presenting an impassable barrier between them. This country was the retreat of smugglers, robbers, and culprits of every description. According to another engineer, Mr. Griffith,

this tract, in 1824, was a wild, neglected, and deserted country, without roads, culture, or civilization. The government ordered roads to be made through this barren district. In 1829, in less than five years after the commencement of the roads, Mr. Griffith thus describes the change which had been produced. "A very considerable improvement has already taken place in the vicinity of the roads, both in the industry of the inhabitants and the appearance of the country. At the commencement of the works, the people flocked into them, seeking employment at any rate; their looks haggard, their clothing wretched; they rarely possessed any tools or implements beyond a small, ill-shaped spade; and nearly the whole face of the country was unimproved. Since the completion of the roads, rapid strides have been made; upwards of sixty new lime-kilns have been built; carts, plows, harrows, and improved implements have become common; new houses of a better class have been built, new inclosures made, and the country has become perfectly tranquil, and exhibits a scene of industry and exertion at once pleasing and remarkable. A large portion of the money received for labor has been husbanded with care, laid out in building substantial houses, and in the purchase of stock and agricultural implements; and numerous examples might be shown of poor laborers, possessing neither money, houses, nor land, when first employed, who in the past year have

been enabled to take farms, build houses, and stock their land."

But the evidence of Mr. Griffith is not the only proof which we can offer of the effects of such works upon the condition of the people. Another witness, Mr. Kelly, thus describes their condition before and after the roads were made. "At Abbeyfeale and Brosna above half of the congregation at mass on Sundays were barefoot and ragged, with small straw hats of their own manufacture, felt hats being worn only by a few. Hundreds, or even thousands of men, could be got to work for sixpence a day if it had been offered. The farmers were mostly in debt, and many families went to beg in Tipperary and other parts. The condition of the people is now very different; the congregations at the chapels are now as well clad as in other parts; the demand for labor is increased, and a spirit of industry is getting forward, since the new roads have become available." Mr. Kelly gives also a curious illustration of the influence of these road-improvements upon the retail trade of the district. "A hatter, at Castle-island, had a small field through which the new road passed; this part next the town was not opened until 1826. In making arrangements with him for his damages, he said, that he ought to make me (the engineer) a present of all the land he had, for that the second year I was at the roads he sold more hats to the people of the mountains alone, than he did for seven years before to the high and low lands together.

Although he never worked a day on the roads, he got comfort and prosperity by them."

The hatter of Castle-island got comfort and prosperity by the roads, because the man who had to sell and the man who had to buy were brought closer to each other by means of the roads. When there were no roads, the hatter kept his goods upon the shelf, and the laborer in the mountains went without a hat. When the laborer and the hatter were brought together by the roads, the hatter soon sold off his stock, and the manufacturer of hats went to work to produce him a new stock; while the laborer, who found the advantage of having a hat, also went to work to earn more money, that he might pay for another when he should require it. It became a fashion to wear hats, and of course a fashion to work hard, and to save time, to be able to pay for them. Thus the road created industry on both sides, on the side of the producer of hats and that of the consumer.

But there are people who can understand the value of a road, who cannot perceive that of a steam-engine. Let us see what the steam-engine does for communication.

The establishment of steam-boats between England and Ireland has greatly contributed to the prosperity of both countries. How have steam-boats done this? They have brought the people closer together. They have made the closely-packed million of people who live in the country round Liverpool, the neighbours of the small farmers and pea-

sants who live amongst the rich valleys of Ireland. The steam-boat has given cheaper food and more of it to the manufacturers on the banks of the Mersey, and cheaper clothes and more of them to the laborers on the banks of the Shannon. In other words, to use the language of an intelligent witness before a committee of the house of Commons, "Steam-navigation has given to Ireland the dearest and best market for her agricultural produce of all kinds, as well as the cheapest and best market from which to bring manufactures of all kinds for the consumption of her population in return." We shall see how these two causes operate to increase the comforts, by lessening the cost of production to both parties; and we shall see these effects most plainly in the facts stated by an accurate observer, Mr. Williams, who gave his evidence last year to parliament, on the condition of the people of Ireland.

Mr. Williams says, that before the steam-boats were established, there was little trade in the smaller articles of farming production, such as poultry and eggs. The first trading steam-boat from Liverpool to Dublin was set up in 1824; there are now forty such boats between England and Ireland. The sailing vessels were from one week to two or three weeks on the passage; the voyage from Liverpool to Dublin is now performed in fourteen hours. Reckoning ten miles for an hour, Dublin and Liverpool are 140 miles apart; with the old vessels, taking twelve days as the

average time of the voyage, they were separated as completely as they would be by a distance of 2880 miles. What is the consequence? "Traders may now have from any of the manufacturing towns in England, within two or three days, even the smallest quantity of any description of goods;" and thus, "one of the effects has been to give a productive employment to the capital of persons in secondary lines of business, that formerly could not have been brought into action." Mr. Williams adds, "I am a daily witness to the intercourse by means of the small traders themselves between England and Ireland. Those persons find their way into the interior of England, and purchase manufactured goods themselves. They are of course enabled to sell them upon much better terms in Ireland; and I anticipate that this will shortly lead to the creation of shops and other establishments in the interior of Ireland, for the sale of a great variety of articles which are not now to be had there." And how do the small dealers in English manufactured goods find purchasers in the rude districts of Ireland for our clothes and our hardware? Because the little farmers have sent us their butter and eggs and poultry, and have either taken our manufactures in exchange, or have taken back our money to purchase our manufactures, which is the same thing. Many millions of eggs, collected amongst the very poorest classes by the industry of women and children, are annually sent from Dublin to Liverpool. Mr. Williams

has known fifty tons, or eight hundred and eighty thousand eggs, shipped in one day, as well as ten tons of poultry; and he says, this is quite a new creation of property. It is a creation of property that has a direct tendency to act upon the condition of the poorer classes in Ireland; for the produce is laid out in providing clothes for the females and children of the families who engage in rearing poultry and collecting eggs. Thus the English manufacturer is bettered, for he has a new market for his manufactures, which he exchanges for cheap provisions; and the dealer in poultry and eggs has a new impulse to this branch of industry, because it enables him to give clothes to his wife and children.

This exchange of benefits—this advancement in the condition of both parties—this creation of produce and of profitable labor—this increase in the number of laborers—could not have taken place without machinery. That machinery is the carriage which conveys the produce to the river, and the steam-boat which makes a port in another country much nearer, for practical purposes, than the market-town of a thinly-peopled district. A new machinery is added; the steam-carriage running on the rail-road, which, in the case of the Liverpool and Manchester rail-road, as one of the witnesses truly says, "is like carrying Liverpool forty miles into the interior, and thus extending the circle to which the supply will be applicable." The last invention perfects all the inventions which have preceded

it. The village and the city are brought close together, in effect, and yet retain all the advantages of their local separation;—the port and the manufactory are divided only by two hours' distance in time, while their distance in space affords room for all the various occupations which contribute to the perfection of either. The whole territory of Great Britain and Ireland is more compact, more closely united, more accessible, than was a single county two centuries ago.* Men can exchange their commodities at the best market; the seller and the buyer are each free to choose their market. If Ireland sends to Liverpool more cattle than Liverpool can consume, they can go upon the rail-road to Manchester. If Manchester has a cheap stock of cotton cloth, which Liverpool does not want for America, the pieces will find their way to the small dealers in the hamlets of Ireland.

And there are some men who say that this wonderful communication, the greatest triumph of modern skill, is not a blessing;—for the machinery has put somebody out of employ. Baron Humboldt, a traveller in South America, tells us, that upon a road being made over a part of the great chain of mountains, called the Andes, the government was petitioned against the road, by a body of men, who for centuries had gained a living by carrying travellers, in baskets strapped upon their backs, over the fearful rocks which only these guides

* See Appendix, No. VI. p. 213.

could cross. Which was the better course—to make the road, and create the thousand employments belonging to freedom of intercourse, for these very carriers of travellers, and for all other men; or to leave the mountains without a road, that the poor guides might gain a premium for risking their lives in an unnecessary peril?

CHAPTER VIII.

The people who live in small villages, or in scattered habitations in the country, have certainly not so many *direct* benefits from machinery as the inhabitants of towns. They have the articles at a cheap rate, which machines produce, but there are not so many machines at work for them as for the inhabitants of towns. From want of knowledge they are unable to perceive the connexion between a cheap coat or a cheap tool, and the machines which make them plentiful, and therefore cheap. But even they, when the saving of labor by a machine is a saving which immediately affects them, are not slow to acknowledge the benefits they derive from that best of economy. The scriptures allude to the painful condition of the "hewers of wood" and the "drawers of water;" and certainly, in a state of society where there are no machines at all, or very rude machines, to cut down a tree and cleave it into logs, or to

raise a bucket from a well, are very laborious occupations, the existence of which, to any extent, amongst a people, would mark them as remaining in a wretched condition. In our own country, at the present day, there are not many houses, in situations where water is at hand, that have not the windlass, or what is better, the pump, to raise this great necessary of life from the well. Some cottagers, however, have no such machines, and bitterly do they lament the want of them. We once met an old woman in a country district, tottering under the weight of a bucket, which she was laboring to carry up a hill. We asked her how she and her family were off in the world. She replied, that she could do pretty well with them, for they could all work, if it were not for one thing—it was one person's labor to fetch water from the spring; but, said she, if we had a pump handy, we should not have much to complain of. This old woman very wisely had no love of labor for its own sake; she saw no advantage in the labor of one of her family being given for the attainment of a good, which she knew might be attained by a very common invention. She wanted a machine to save that labor. Such a machine would have set at liberty a certain quantity of labor which was previously employed unprofitably; in other words, it would have left her or her children more time for more profitable work, and then the family earnings would have been increased.

But there is another point of view in which

this machine would have benefited the good woman and her family. Water is not only necessary to drink and to prepare food with, but it is necessary for cleanliness, and cleanliness is necessary for health. If there is a scarcity of water, or if it requires a great deal of labor to obtain it, (which comes to the same thing as a scarcity,) the uses of water for cleanliness will be wholly, or in part, neglected. If the neglect becomes a habit, which it is sure to do, disease, and that of the worst sort, cannot be prevented.

When men gather together in large bodies, and inhabit towns or cities, a plentiful supply of water is the first thing to which they direct their attention. If towns are built in situations where pure water cannot be readily obtained, the inhabitants, and especially the poorer sort, suffer even more misery than results from the want of bread or clothes. In some cities of Spain, for instance, where the people understand very little about machinery, water, at particular periods of the year, is as dear as wine; and the laboring classes are consequently in a most miserable condition. In London, on the contrary, water is so plentiful, that twenty-nine millions of gallons are daily supplied to the inhabitants; which quantity, distributed to about one hundred and twenty-five thousand houses and other buildings, is at the rate of above two hundred gallons every day to each house. To many of the houses this water is, by the aid of machinery, not only delivered to the kitchens and

wash-houses on the ground-floors, where it is most wanted, but is sent up to the very tops of the houses, to save even the comparatively little labor of fetching it from the bottom. All this is done at an average cost to each house of about two-pence a-day; which is a less price than the labor of an able-bodied man would be worth to fetch a single bucket, from a spring half a mile from his own dwelling.

And how did the inhabitants of London set about getting this great supply of water? How did they get a sufficient quantity, not only to use as much as they please for drinking, for cooking, and for washing, but obtained such an abundance, that the poorest man can afford to throw it away as if it cost nothing, into the channels which are also provided for carrying it off, and thus to free his own room or house from every impurity; and by so doing to render this vast place one of the most healthful cities in the world? They set about doing this great work by machinery; and they began to do it when the value of machinery in other things was not so well understood as it is now. As long ago as the year 1236, when a great want of water was felt in London, the little springs being blocked up and covered over by buildings, the ruling men of the city caused water to be brought from Tyburn, which was then a distant village, by means of pipes; and they laid a tax upon particular branches of trade to pay the expense of this great blessing to all. In succeeding times more pipes and conduits, that is, more machinery, was established for the same good

purpose; and two centuries afterwards, King Henry the Sixth gave his aid to the same sort of works, in granting particular advantages in obtaining lead for making the pipes. The reason for this aid to such works was, as the royal decree set forth, that they were "for the common utility and decency of all the city, and *for the universal advantage*;" and a very true reason this was. As this great town more and more increased, more water-works were found necessary; till at last, in the reign of James the First, which was nearly two hundred years after that of Henry the Sixth, a most ingenious and enterprising man, and a great benefactor to his country, Hugh Myddleton, undertook to bring a river of pure water above thirty-eight miles out of its natural course, for the supply of London. He persevered in this immense undertaking, in spite of every difficulty, till he at last accomplished that great good which he had proposed, of bringing wholesome water to every man's door. At the present time, the New River, which was the work of Hugh Myddleton, supplies thirteen millions of gallons of water every day; and though the original projector was ruined by the undertaking, in consequence of the difficulty which he had in procuring proper support, such is now the general advantage of the benefit which he procured for his fellow-citizens, and so desirous are the people to possess that advantage, that a share in the New River Company, which was at first sold at one hundred pounds, is now worth fifteen thousand pounds.

Before the people of London had water brought to their own doors, and even into their very houses, and into every room of their houses where it is desirable to bring it, they were obliged to send for this great article of life—first, to the few springs which were found in the city and its neighbourhood, and secondly, to the conduits and fountains, which were imperfect mechanical contrivances for bringing it. The service-pipes to each house are more perfect mechanical contrivances; but they could not have been rendered so perfect without engines, which force the water above the level of the source from which it is taken. When the inhabitants fetched their water from the springs and conduits, there was a great deal of human labor employed; and as in every large community there are always people ready to perform labor for money, many persons obtained a living by carrying water. When the New River had been dug, and the pipes had been laid down, and the engines had been set up, it is perfectly clear that there would have been no further need for these water-carriers. When the people of London could obtain two hundred gallons of water for two-pence, they would not employ a man to fetch a single bucket from the river or the fountain at the same price. They would not, for the mere love of employing human labor directly, continue to buy an article very dear, which, by mechanical aid, they could buy very cheap. If they had resolved, from any mistaken notions about machinery, to continue to em-

ploy the water-carriers, they must have been contented with one gallon of water a day instead of two hundred gallons. Or if they had consumed a larger quantity, and continued to pay the price of bringing it to them by hand, they must have denied themselves other necessaries and comforts. They must have gone without a certain portion of food, or clothing, or fuel, which they are now enabled to obtain by the saving in the article of water. To have had for each house two hundred gallons of water, and in having this two hundred gallons of water, to have had the cleanliness and health which result from its use, would have been utterly impossible. At two-pence a gallon, which would not have been a large price considering the distances to which it must have been carried, the same supply of water would have cost about nine millions of pounds sterling a year, and would have employed, at the wages of two shillings a day, more than one-half of all the present inhabitants of London, or eight hundred thousand people, that is, about four times the number of able-bodied men altogether contained in the metropolis. Such a supply therefore would have been utterly out of the question. To have supplied one gallon instead of two hundred gallons to each house at the same rate of wages, would have required the labor of twelve thousand men. It is evident that even this number could not have been employed in such an office: because had there been no means of supplying London with water but the means

of human hands, London could not have increased to one twentieth of its present size;—there would not have been one twentieth part of the population to have been supplied—and therefore six hundred water-carriers would have been an ample proportion to this population.

There is now, certainly, no labor to be performed by water-carriers. But suppose that five hundred years ago, when there were a small number of persons who gained their living by such drudgery, they had determined, with as much justice and reason as the present breakers of machinery, to prevent the bringing of water by pipes into London. Suppose also that they had succeeded; and that up to the present day we had no pipes or other mechanical aids for supplying the water. It is quite evident that if this misfortune had happened—if the welfare of the many had been retarded, (for it never could have been finally stopt,) by the ignorance of the few—London, as we have already shown, would not have had a twentieth part of its present population; and the population of every other town, depending as population does upon the increase of *profitable* labor, could never have gone forward. How then would the case have stood as to the amount of labor engaged in the supply of water? A few hundred, at the utmost a few thousand, carriers of water would have been employed throughout the kingdom; while the smelters and founders of iron of which water-pipes are made, the laborers who

lay down these pipes, the founders of lead who make the service-pipes, and the plumbers who apply them; the carriers, whether by water or land, who are engaged in bringing them to the towns, the manufacturers of the engines which raise the water, the builders of the houses in which the engines stand,—these, and many other laborers and mechanics who directly and indirectly contribute to the same public advantage, could never have been called into employment. To have continued to use the power of the water-carriers, would have rendered the commodity two hundred times dearer than it is supplied by mechanical power. The present cheapness of production, by mechanical power, supplies employment to an infinitely greater number of persons than could have been required by a perseverance in the rude and wasteful system which belonged to former ages of ignorance and wretchedness.

The supply of artificial light, by *gas*, may be proved to be an equal advantage to the consumers and the producers, by the same course of argument.

CHAPTER IX.

There was a time when the people of England were very inferior to those of the Low Countries, of France, and of Germany, in

various productions of manufacturing industry. We first gave an impulse to our woollen trade, which for several centuries was the great staple of the country, by procuring foreign workmen to teach our people their craft. Before that period the nations on the continent had a proverb against us. They said, "the stranger buys of the Englishman the skin of the fox for a groat, and sells him the tail again for a shilling." The proverb meant, that we had not skill to convert the raw material into an article of use, and that we paid a large price for the labor and ingenuity which made our native material available to ourselves.

But still our intercourse, such as it was then, with "the stranger" was better than no intercourse. We gave the rough and stinking fox's skin for a groat, and we got the nicely-drest tippet for a shilling. The next best thing to dressing the skin ourselves, was to pay other people for dressing it. Without foreign communication we should not have got that article of clothing at all.

All nations that have made any considerable advance in civilization have been commercial nations. The arts of life are very imperfectly understood in countries which have little communication with the rest of the world, and consequently the inhabitants are poor and wretched;—their condition is not bettered by the exchange with other countries, either of goods or of knowledge. They have the fox' skin, but they do not know how to convert i

into value, by being furriers themselves, or by communication with "stranger" furriers.

The people of the East, amongst whom a certain degree of civilization has existed from high antiquity, were not only the growers of many productions which were unsuited to the climate and soil of Europe, but they were the manufacturers also. Cotton, for instance, was cultivated from time immemorial in Hindostan, in China, in Persia, and in Egypt. Cotton was a material easily grown and collected; and the patient industry of the people by whom it was cultivated, their simple habits, and their few wants, enabled them to send into Europe their manufactured stuffs of a fine and durable quality, under every disadvantage of land-carriage, even from the time of the ancient Greeks. Before the discovery, however, of the passage to India by the Cape of Good Hope, cotton goods in Europe were articles of great price and luxury. A French writer, M. Say, well observes, that although cotton stuffs were cheaper than silk, (which was formerly sold for its weight in gold,) they were still articles which could only be purchased by the most opulent; and that, if a Grecian lady could awake from her sleep of two thousand years, her astonishment would be unbounded, to see a simple country girl clothed with a gown of printed cotton, a muslin kerchief, and a colored shawl.

When India was open to the ships of Europe, the Portuguese, the Dutch, and the English, sold cotton goods in every market, in consider-

able quantities. These stuffs bore their Indian names of calicoes and muslins; and whether bleached or dyed, were equally valued as amongst the most useful and ornamental articles of European dress.

In the seventeenth century, France began to manufacture into stuffs the *raw* cotton imported from India, as Italy had done a century before. A cruel act of despotism drove the best French workmen, who were Protestants, into England, and we learnt the manufacture. The same act of despotism, the revocation of the edict of Nantes, caused the settlement of silk-manufacturers in Spitalfields. We did not make any considerable progress in the art, nor did we use the material of cotton exclusively in making up the goods. The warp, or longitudinal threads of the cloth, were of flax, the weft only was of cotton; for we could not twist it hard enough by hand to serve both purposes. This weft was spun entirely by hand with a distaff and spindle,—the same tedious process which prevails amongst the natives of India. Our manufacture, in spite of all these disadvantages, continued to increase; so that about 1760, although there were fifty thousand spindles at work in Lancashire alone, the weaver found the greatest difficulty in procuring a sufficient supply of thread. Neither weaving nor spinning was then carried on in large factories. They were domestic occupations. The women of a family worked at the distaff or the hand-wheel, and there were two operations necessary in this department;

roving, or coarse spinning, reduced the carded cotton to the thickness of a quill, and the spinner afterwards drew out and twisted the roving into weft fine enough for the weaver A writer on the cotton manufacture, Mr. Guest, states, that very few weavers could procure weft enough to keep themselves constantly employed. "It was no uncommon thing," he says, "for a weaver to walk three or four miles in a morning, and call on five or six spinners, before he could collect weft to serve him for the remainder of the day; and when he wished to weave a piece in a shorter time than usual, a new ribbon or gown was necessary to quicken the exertions of the spinner."

That the manufacture should have flourished in England at all under these difficulties is honorable to the industry of our country; for the machinery used in weaving was also of the rudest sort, so that if the web was more than three feet wide, the labor of two men was necessary to throw the shuttle. English cotton goods, of course, were very dear, and there was little variety in them. The cloth made of flax and cotton was called fustian. We still received the calicoes and printed cottons from India.

In a country like ours, where men have learnt to think, and where ingenuity therefore is at work, a deficiency in material or in labor to meet the demand of a market is sure to call forth invention. It is nearly a century ago since it was perceived that spinning by machinery might give the supply which human

labor was inadequate to produce, because, doubtless, the remuneration for that labor was very small. The work of the distaff, as it was carried on at that period, in districts partly agricultural, and party commercial, was generally an employment for the spare hours of the young women, and the easy industry of the old. It was a labor that was to assist in maintaining the family,—not a complete means for their maintenance. The supply of yarn was therefore insufficient, and ingenious men applied themselves to remedy that insufficiency. Spinning mills were built at Northampton in 1733, in which it is said, although we have no precise account of it, that an apparatus for spinning was erected. A Mr. Lawrence Earnshaw, of Mottram, in Cheshire, is recorded to have invented a machine, in 1753, to spin and reel cotton at one operation; which he showed to his neighbors and then destroyed it, through the generous apprehension that he might deprive the poor of bread. We must admire the motive of this good man, although we are now enabled to show that his judgment was mistaken. Richard Arkwright, a barber of Preston, invented, in 1769, the principal part of the machinery for spinning cotton, and by so doing, he gave bread to about two millions of people, instead of fifty thousand; and, assisted by subsequent inventions, raised the importation of cotton wool from India from less than two millions of pounds per annum, to two hundred of millions;—set in motion six millions of spindles, instead of fifty thousand;

—and increased the annual produce of the manufacture from two hundred thousand pounds sterling to thirty-six million pounds.

And how did he effect this great revolution? He asked himself whether it was not possible, instead of a wheel which spins a single thread of cotton at a time, and by means of which the spinner could obtain in twenty-four hours about two ounces of thread,—whether it might not be possible to spin the same material upon a great number of wheels, from which many hundreds of threads might issue at the same moment. The difficulty was in giving to these numerous wheels, spinning so many threads, the peculiar action of two hands when they pinch, at a little distance from each other, a lock of cotton, rendering it finer as it is drawn out. It was necessary, also, at the same time, to imitate the action of the spindle, which twisted together the filaments at the moment they had attained the necessary degree of fineness. It would be extremely difficult, if not impossible, to give an adequate idea, by words, of the complex machinery by which Arkwright accomplished his object, or of the subsequent improvements which have been made upon that machinery. But it may be desirable to describe that chief portion of his invention, which enabled rollers to do the work of human fingers, with much greater precision, and incomparably cheaper.

We must suppose that by the previous operation of carding, the cotton wool has been so combed and prepared as to be formed into

a long untwisted line of about the thickness of a man's finger. This line so formed (after it has been introduced into the machine we are about to describe) is called a *roving*, the old name in hand-spinning.

In order to convert this roving into a thread, it is necessary that the fibres, which are for the most part curled up, and which lie in all directions, should be stretched out and laid lengthways, side by side; that they should be pressed together so as to give them a more compact form; and that they should be twisted, so as to unite them all firmly together. In the original method of spinning by the distaff, those operations were performed by the finger and thumb, and they were afterwards effected with greater rapidity, but less perfectly, by means of the long-wheel and spindle. For the same purpose, Arkwright employed two pairs of small rollers, the one pair being placed at a little distance in front of the other. The lower roller in each pair is furrowed or fluted lengthwise, and the upper one is covered with leather; so that, as they revolve in contact with each other, they take fast hold of the cotton which passes between them. Both pairs of rollers are turned by machinery, which is so contrived that the second pair shall turn round with much more swiftness than the first. Now suppose that a roving is put between the first pair of rollers. The immediate effect is merely to press it together into a more compact form. But the roving has but just passed through the first pair of

rollers, when it is received between the second pair; and as the rollers of the second pair revolve with greater velocity than those of the first, they draw the roving forwards with greater rapidity than it is given out by the first pair. Consequently, the roving will be lengthened in passing from one pair to the other; and the fibres of which it is composed will be drawn out and laid lengthways side by side. The increase of length will be exactly in proportion to the increased velocity of the second pair of rollers.

Two or more rovings are generally united in this operation. Thus, suppose that two rovings are introduced together between the first pair of rollers, and that the second pair of rollers moves with twice the velocity of the first. The new roving thus formed by the union of the two, will then be of exactly twice the length of either of the original ones. It will therefore contain exactly the same quantity of cotton per yard. But its parts will be very differently arranged, as its fibres will be drawn out longitudinally, and will be thus much better fitted for forming a thread. This operation of doubling and drawing is repeated as often as is found necessary, and the requisite degree of twist is given by a machine similar to the spindle and fly of the common flax-wheel.

The fineness with which the cotton thread can be drawn out by this machinery, may be gathered from the fact, that Mr. John Pollard, of Manchester, spun, in 1792, on the mule, (the name of a particular description of the

cotton-spinning machinery,) no fewer than two hundred and seventy-eight hanks of yarn, forming a thread upwards of one hundred and thirty-two miles in length, from a single pound of raw cotton. Of the rapidity with which some portions of the machinery work, you may form an idea, when you learn that the very finest thread which is used in making lace is passed through the strong flame of a lamp, which burns off the fibres, without burning the thread itself. The velocity with which the thread moves is so great, that you cannot perceive any motion at all. The line of thread passing off a wheel through the flame, looks as if it were perfectly at rest; and it appears a miracle that it is not burnt.

The invention of Arkwright—the substitution of rollers for fingers—changed the commerce of the world. The machinery by which a man or woman, or even a child could produce two hundred threads where one was produced before, caused a cheapness of production much greater than that of India, where human labor is scarcely worth any thing. But the fabric of cotton was also infinitely improved by the machinery. The hand of the spinner was unequal in its operations. It sometimes produced a fine thread, and sometimes a coarse one; and therefore the quality of the cloth could not be relied upon. The yarn which is spun by machinery is sorted with the greatest exactness, and numbered according to its quality. This circumstance alone, which could only result from

machinery, has a direct tendency to diminish the cost of production. Machinery not only adds to human power, and economizes human time, but it works up the most common materials into articles of value, and equalizes the use of valuable materials. Thus, in linen of which the thread is spun by the hand, a thick thread and a thin thread will be found side by side: and, therefore, not only is material wasted, but the fabric is less durable, because it wears unequally.

These circumstances—the diminished cost of cotton goods, and the added value to the quality—have rendered it impossible for the cheap labor of India to come into the market against the machinery of Europe. The trade in Indian cotton goods is gone for ever. Not even the caprices of fashion can have an excuse for purchasing the dearer commodity. We make it cheaper, and we make it better. The trade in cotton, as it exists in the present day, is the great triumph of human ingenuity. We bring the raw material from the country of the people who grow it, on the other side of our globe; we manufacture it by our machines into articles which we used to buy from them ready made; and taking back those articles to their own markets, encumbered with the cost of transport for fourteen thousand miles, and encumbered also with the taxes which the State has laid upon it in many various ways, we sell it to these very people cheaper than they can produce it themselves, and they buy it therefore with eagerness.

CHAPTER X.

It is just possible that some of you will say it matters not to us, the working men of England, whether the people of India sell us raw cotton or piece goods; or whether the trade in cotton amounts to one million a year or thirty-six millions. You may want to know how you individually, whether laborers or mechanics, are benefited by these changes, which look so large in figures. We will endeavor to tell you how you are benefited.

Of the cotton cloth made in England, three hundred and sixty million yards are exported, and three hundred and ninety-nine million yards are retained for home consumption. This was the state of the trade upon an average of years from 1824 to 1828. You are, doubtless, benefited very greatly, though indirectly, by the cotton cloth and the cotton yarn which goes out of the country. The difference in the value between the raw cotton and the cotton yarn or cloth, is the price of your industry, and of the profits of capital which sets your industry in motion. At that price you buy foreign produce, by which purchase you bring many articles of necessity and luxury within your reach. But this, you say, is a doubtful good. The good is not doubtful; but the objects which produce the good are spread over a large surface. We shall confine your attention therefore to one object.

Nearly twenty years after Arkwright had begun to spin by machinery, the price of a particular sort of cotton yarn much used in the manufacture of calico was thirty-eight shillings a pound. That same yarn is now sold for between three and four shillings, or one-twelfth of its price forty years ago. If cotton goods were worn only by the few rich, as they were worn in ancient times, and even in the latter half of the last century, that difference of price would not be a great object; but the price is a very important object when every man, woman, and child in the United Kingdom has to pay it. The four hundred million yards of cloth which are annually retained for home consumption, distributed amongst twenty-five millions of population, allows sixteen yards every year for each individual. We will suppose that no individual would buy these sixteen yards of cloth unless he or she wanted them; that this plenty of cloth is a desirable thing; that it is conducive to warmth and cleanliness, and therefore to health; that it would be a great privation to go without the cloth. At six-pence a yard, the four hundred million yards of cloth amount to ten million pounds sterling. At half-a-crown a yard, which we will take as the average price about five-and-twenty years ago, they would amount to fifty millions of pounds sterling—an amount equal to all the taxes annually paid in Great Britain and Ireland. At twelve times the present price, or six shillings a yard, which proportion we get by knowing

the price of yarn forty years ago and at the present day, the cost of four hundred million yards of cotton cloth would be one hundred and twenty millions of pounds sterling. It is perfectly clear that no such sum of money could be paid for cotton goods, and that, in fact, instead of ten millions being spent in this article of clothing by persons of all classes, in consequence of the cheapness of the commodity, we should go back to very nearly the same consumption that existed before Arkwright's invention, that is, to the consumption of the year 1750, when the whole amount of the cotton manufacture of the kingdom did not exceed the annual value of two hundred thousand pounds. At that rate of value, the quantity of cloth manufactured could not have been equal to one-five-hundredth part of that which is now manufactured for home consumption. So that thirty-one people each now consume sixteen yards of cotton cloth, where one person, eighty years ago, consumed one yard. We ask you, therefore, if this vast difference in the comforts of every family, by the ability which they now possess of easily acquiring warm and healthful clothing, is not a clear gain to all society, and to every one of you as a portion of society? It is more especially a gain to the females and the children of your families, whose condition is always degraded when clothing is scanty. The power of procuring cheap clothing for themselves, and for their children, has a tendency to raise the condition of females more than any

other addition to their stock of comfort. It cultivates habits of cleanliness and decency; and those are little acquainted with the human character who can doubt whether cleanliness and decency are not only great aids to virtue, but virtues themselves. John Wesley said that cleanliness was next to godliness. There is little self-respect amidst dirt and rags, and without self-respect there can be no foundation for those qualities which most contribute to the good of society. The power of procuring useful clothing at a cheap price has raised the condition of women amongst us, and the influence of the condition of women upon the welfare of a community can never be too highly estimated.

That the manufacture of cotton by machinery has produced one of the great results for which machinery is to be desired, namely, cheapness of production, cannot, we think, be doubted. If increased employment of human labor has gone along with that cheapness of production, even the most prejudiced can have no doubt of the advantages of this machinery to all classes of the community.

At the time that Arkwright commenced his machinery, a man named Hargrave, who had set up a less perfect invention, was driven out of Lancashire, at the peril of his life, by a combination of the old spinners by the wheel. In 1789, when the spinning machinery was introduced into Normandy, the hand-spinners there also destroyed the mills, and put down the manufacture for a time. Lancashire and Normandy are now, in England and France,

the great seats of the cotton manufacture. The people of Lancashire and Normandy had not formerly the means, as we have now, of knowing that cheap production produces increased employment. There were many examples of this principle formerly to be found in arts and manufactures; but the people were badly educated upon such subjects, principally because studious and inquiring men had thought such matters beneath their attention. We live in times more favorable for these researches. The people of Lancashire and Normandy, at the period we mention, being ignorant of what would conduce to their real welfare, put down the machines. In both countries they were a very small portion of the community that attempted such an illegal act. The weavers were interested in getting cotton yarn cheap, so the combination was opposed to their interests; and the spinners were chiefly old women and girls, very few in number, and of little influence. Yet they and their friends, both in England and France, made a violent clamor; and but for the protection of the laws, the manufactories in each country would never have been set up. What was the effect upon the condition of this very population? M. Say, in his "Complete Course of Political Economy," (that is, the science which teaches how the wealth of a people may be best advanced,) states, upon the authority of an English manufacturer of fifty years' experience, that, in ten years after the introduction of the machines, the people employed in the trade, spinners and

weavers, were more than forty times as many as when the spinning was done by hand. It was calculated, in 1825, that the power of twenty thousand horses was employed in the spinning of cotton; and that the power of each horse yielded, with the aid of machinery, as much yarn as one thousand and sixty-six persons could produce by hand. If this calculation be correct, and there is no reason to doubt it, the spinning machinery of Lancashire alone produced, in 1825, as much yarn as would have required twenty-one million three hundred and twenty thousand persons to produce with the distaff and spindle. This immense power, which is nearly equal to the population of the United Kingdom, might be supposed to have superseded human labor altogether in the production of cotton yarn. It did no such thing. It gave a new direction to the labor that was formerly employed at the distaff and spindle; but it increased the quantity of labor altogether employed in the manufacture of cotton, at least a hundred fold. It increased it too where an increase of labor was most desirable. It gave constant, easy, and not unpleasant occupation to women and children. In all the departments of cotton-spinning, and in many of those of weaving by the power-loom, women and children are employed. There are degrees, of course, in the agreeable nature of the employment, particularly as to its being more or less cleanly. But there are extensive apartments in large cotton factories, where great numbers of females are daily engaged in

processes which would not soil the nicest fingers, dressed with the greatest neatness, and clothed in materials (as all women are now clothed) that were set apart for the highest in the land a century ago. And yet there are some who regret that the aged crones no longer sit in the cottage chimney, earning a few pence daily by their rude industry at the wheel!

The creation of employment amongst ourselves by the cheapness of cotton goods produced by machinery, is not to be considered as a mere change from the labor of India to the labor of England. It is a creation of employment, operating just in the same manner as the machinery did for printing books. The Indian, it is true, no longer sends us his calicoes and his colored stuffs; we make them ourselves. But he sends us forty times the amount of raw cotton that he sent when the machinery was first set up. In 1781 we imported five million pounds of cotton wool. In 1828 we imported two hundred and ten million pounds—enough to make twelve hundred and sixty million yards of cloth—which is about two yards apiece for every human being in the world. The workman on the banks of the Ganges, (the great river of India,) is no longer weaving calicoes for us, in his loom of reeds under the shade of a mango tree; but he is gathering for us forty times as much cotton as he gathered before, and making forty times as much indigo for us to color it with. The export of cotton has made such a demand upon the

Indian power of labor, that even the people of Hindostan, adopting European contrivances, have introduced machinery to pack the cotton. Bishop Heber says, that he was frequently interested by seeing, at Bombay, immense bales of cotton lying on the piers, and the ingenious screw, by which an astonishing quantity is pressed into the canvas bags. The Chinese, on the contrary, from the want of these contrivances to press the cotton so close in bags, sell their cotton to us at much less profit; for they pack it so loosely, that it occupies three times the bulk of the Indian cotton, and the freight costs twelve times the price on this account. When the Chinese acquire the knowledge from other nations, which their institutions now shut out, they will know the value of mechanical skill, in preference to unassisted manual labor.

The arguments for the use of machinery, that may be derived from the manufacture of SILK, are precisely the same as those we have exhibited in the manufacture of cotton. The cost of production has been lessened—the employment of the producers has been increased. When the frame-work knitters of silk stockings petitioned Oliver Cromwell for a charter, they said, "the Englishman buys silk of the stranger for twenty marks, and sells him the same again for one hundred pounds." The higher pride of the present day is, that we buy three million and a half pounds of raw silk from the stranger, employ half a million

of our own people in the manufacture of it by the aid of machinery, and sell it to the stranger, and our own people, at a price as low as that of the calico of half a century ago.

The manufactures of WOOLLEN CLOTH, and of LINEN CLOTH, partly carried on with materials produced by ourselves, and partly with wool and flax bought from other nations, have increased, with the use of machinery, in the same way as the cotton manufacture. In both cases, the article produced is diminished in price.

CHAPTER XI.

THE beaver builds his huts with the tools which nature has given him. He gnaws pieces of wood in two with his sharp teeth, so sharp, that the teeth of a similar animal, the Agouti, form the only cutting-tool which some rude nations possess. When the beavers desire to move a large piece of wood, they join in a body to drag it along.

Man has not teeth that will cut wood. But he has reason, which directs him to the choice of much more perfect tools.

Some of the great monuments of antiquity, such as the pyramids of Egypt, are constructed of enormous blocks of stone brought from distant quarries. We have no means of estimating, with any accuracy, the mechanical

knowledge possessed by the people engaged in these works. It was, probably, very small, and consequently, the human labor employed in such edifices was not only enormous in quantity, but exceedingly painful to the workmen. The Egyptians, according to Herodotus, a Greek writer who lived two thousand five hundred years ago, hated the memory of the kings who built the pyramids. He tells us that the great pyramid occupied a hundred thousand men for twenty years in its erection, without counting the workmen who were employed in hewing the stones, and in conveying them to the spot where the pyramid was built. Herodotus speaks of this work as a torment to the people; and doubtless, the labor engaged in raising huge masses of stone, that was extensive enough to employ a hundred thousand men for twenty years, which is equal to two million of men for one year, must have been fearfully tormenting without machinery, or with very imperfect machinery. It has been calculated that the steam-engines of England, worked by thirty-six thousand men, would raise the same quantity of stones from the quarry, and elevate them to the same height as the great pyramid, in the short time of eighteen hours. The people of Egypt groaned for twenty years under this enormous work. The laborers groaned because they were sorely tasked; and the rest of the people groaned because they had to pay the laborers. The laborers lived, it is true, upon the wages of

their labor, that is, they were paid in food—kept like horses—as the reward of their work. Herodotus says, that it was recorded on the pyramid, that the onions, radishes, and garlic which the laborers consumed, cost sixteen hundred talents of silver; an immense sum, equivalent to several million pounds. But the onions, radishes, and garlic, the bread, and clothes of the laborer, were wrung out of the profitable labor of the rest of the people. The building of the pyramid was an unprofitable labor. There was no immediate or future source of produce in the pyramid; it produced neither food, nor fuel, nor clothes, nor any other necessary. The labor of a hundred thousand men for twenty years, stupidly employed upon this monument, without an object beyond that of gratifying the pride of the tyrant who raised it, was a direct tax upon the profitable labor of the rest of the people.

> "Instead of useful works, like nature great,
> Enormous cruel wonders crush'd the land."

But admitting that it is sometimes desirable for nations and governments to erect monuments which are not of direct utility,—which may have an indirect utility in recording the memory of great exploits, or in producing feelings of reverence or devotion,—it is clearly an advantage that these works, as well as all other works, should be performed in the cheapest manner; that is, that human labor should derive every possible assistance from mechanical aid. We will give you an illustration of the differences of the

application of mechanical aid in one of the first operations of building, the moving a block of stone. The following statements are the result of actual experiment upon a stone weighing ten hundred and eighty pounds.

To drag this stone along the smoothed floor of the quarry required a force equal to seven hundred and fifty-eight pounds. The same stone dragged over a floor of planks required six hundred and fifty-two pounds. The same stone placed on a platform of wood, and dragged over the same floor of planks, required six hundred and six pounds. When the two surfaces of wood were soaped as they slid over each other, the force required to drag the stone was reduced to one hundred and eighty-two pounds. When the same stone was placed upon rollers three inches in diameter, it required, to put it in motion along the floor of the quarry, a force only of thirty-four pounds; and by the same rollers upon a wooden floor, a force only of twenty-eight pounds. You will see, therefore, that without any mechanical aid, it would require the force of four or five men to set that stone in motion. With the mechanical aid of two surfaces of wood soaped, the same weight might be moved by one man. With the more perfect mechanical aid of rollers, the same weight might be moved by a very little child.

From these statements it must be evident that the cost of a block of stone very much depends upon the quantity of labor, necessary to move it from the quarry to the

place where it is wanted to be used. We have seen that, with the simplest mechanical aid, labor may be reduced sixty-fold. With more perfect mechanical aid, such as that of water-carriage, the labor may be reduced infinitely lower. Thus, the streets of London are paved with granite from Scotland, at a moderate expense.

The cost of timber, which enters so largely into the cost of a house, is, in a great degree, the cost of transport. We load two thousand ships yearly with the timber which we import from the Baltic sea, and from North America. In countries where there are great forests, timber-trees are worth nothing where they grow, except there are ready means of transport. In many parts of North America, the great difficulty which the people find is in clearing the land of the timber. The finest trees are not only worthless, but are a positive encumbrance, except when they are growing upon the banks of a great river; in which case the logs are thrown into the water, or formed into rafts, being floated several hundred miles, at scarcely any expense. The same stream which carries them to a sea-port turns a mill to saw the logs into planks; and when sawn into planks the timber is put on shipboard, and carried to distant countries where timber is wanted. Thus mechanical aid alone gives a value to the timber, and by so doing employs human labor. The stream that floats the tree, the sawing-mill that cuts it, the ship that carries

it across the sea, enable men profitably to employ themselves in working it. Without the stream, the mill, and the ship, those men would have no labor, because none could afford to bring the timber to their own doors.

We build in this country more of brick than of stone, because brick earth is found almost everywhere, and stone fit for building is found only in particular districts. Bricks pay to the state a duty of five shillings and tenpence a thousand; and yet at the kilns they may be bought under forty shillings a thousand, which is less than a halfpenny a piece. How is it that bricks are so cheap? Because they are made by machinery. The clay is ground in a horse-mill;—the wooden mould in which every brick is made singly, is a copying machine. One brick is exactly like another brick. Every brick is of the form of the mould in which it is made. Without the mould the workman could not make the brick of uniform dimensions; and without this uniformity the after labor of putting the bricks together would be greatly increased. Without the mould the workman could not form the bricks quickly;—his own labor would be increased ten-fold. Because bricks are cheap, one thousand million bricks, as the excise returns show, are made in England in a year; and thus the simple machine of the mould not only gives employment to a great many brickmakers who would not be employed at all, but also to a great many bricklayers, who would also want employment, if the original

cost of production were so enormously increased.

What an infinite variety of machines, in combination with the human hand, is found in a carpenter's chest of tools! The skilful hand of the workman is the *power* which sets these machines in motion; just as the wind or the water is the power of a mill, or the elastic force of vapor the power of a steam-engine. When Mr. Bolton, the partner of the celebrated James Watt, waited upon George III. to explain one of the great improvements of the steam-engine which they had effected, the king said to him, "What do you sell, Mr. Bolton?" and the honest engineer answered, "What kings, sire, are all fond of—*power*." There are people at Birmingham who let out *power*, that is, there are people who have steam-engines who will lend the use of them, by the day or the hour, to persons who require that saving of labor in their various trades; so that a person who wants the strength of a horse, or half a horse, to turn a wheel for grinding, or for setting a lathe in motion, hires a room, or part of a room in a mill, and has just as much power as he requires. The *power* of a carpenter is in his hand, and the machines moved by that power are in his chest of tools. Every tool which he possesses has for its object to reduce labor, to save material, and to insure accuracy—the objects of all machines. What a quantity of waste, both of time and stuff, is saved by his foot-rule! and when he

chalks a bit of string and stretches it from one end of a plank to the other, to jerk off the chalk from the string, and thus produce an unerring line upon the face of the plank, he makes a little machine, which saves him great labor. Every one of his hundreds of tools, capable of application to an infinite variety of purposes, is an invention to save labor. Without some tool the carpenter's work could not be done at all by the human hand. A knife would do very laboriously what is done very quickly by a hatchet. The labor of using a hatchet, and the material which it wastes, are saved twenty times over by the saw. But when the more delicate operations of carpentry are required;—when the workman uses his planes, his rabbet-planes, his fillisters, his bevils, and his centre-bits, what an infinitely greater quantity of labor is economized, and how beautifully that work is performed, which, without them, would be rough and imperfect! Every boy of mechanical ingenuity has tried with his knife to make a boat; and with a knife only it is the work of weeks. Give him a chisel, and a gouge, and a vice to hold his wood, and the little boat is the work of a day.

If carpenters had not tools to make houses, there would be few houses made; and those that were made, would be as rough as the hut of the savage who has no tools. The people would go without houses, and the carpenter would go without work,—to say nothing of the people, who would also go without work, that now make tools for the carpenter.

How great a variety of things are contained in an ironmonger's shop! Half his store consists of tools of one sort or another to save labor; and the other half consists of articles of convenience or elegance most perfectly adapted to every possible want of the builder or the maker of furniture. The uncivilized man is delighted when he obtains a nail—any nail. A carpenter and joiner, who supply the wants of a highly-civilized community, are not satisfied unless they have a choice of nails, from the finest brad to the largest clasp-nail. A savage thinks a nail will hold two pieces of wood together more completely than any thing else in the world. It is seldom, however, that he can afford to put it to such a use. If it is large enough, he makes it into a chisel. An English joiner knows that screws will do the work more perfectly in some cases than any nail; and therefore we have as great a variety of screws as of nails. The commonest house built in England has hinges, and locks, and bolts. A great number are finished with ornamented knobs to door-handles, with bells and bell-pulls, and a thousand other things that have grown up into necessities, because they save domestic labor, and add to domestic comfort. And many of these things really are necessities. M. Say, a French writer, gives us an example of this; and as his story is an amusing one, besides having a moral, we may as well copy it:—

"Being in the country," says he, "I had an example of one of those small losses which a

family is exposed to through negligence. For the want of a latchet of small value, the wicket of a barn-yard leading to the fields was often left open. Every one who went through drew the door to; but as there was nothing to fasten the door with, it was always left flapping; sometimes open, and sometimes shut. So the cocks and hens, and the chickens, got out, and were lost. One day a fine pig got out, and ran off into the woods; and after the pig ran all the people about the place,—the gardener, and the cook, and the dairy-maid. The gardener first caught sight of the runaway, and, hastening after it, sprained his ankle; in consequence of which the poor man was not able to get out of the house again for a fortnight. The cook found, when she came back from pursuing the pig, that the linen she had left by the fire had fallen down, and was burning; and the dairy-maid having, in her haste, neglected to tie up the legs of one of her cows, the cow had kicked a colt, which was in the same stable, and broken its leg. The gardener's lost time was worth twenty crowns, to say nothing of the pain he suffered. The linen which was burned, and the colt which was spoiled, were worth as much more. Here, then, was caused a loss of forty crowns, as well as much trouble, plague, and vexation, for the want of a latch which would not have cost threepence." M. Say's story is one of the many examples of the truth of the old proverb —"For want of a nail the shoe was lost, for

want of a shoe the horse was lost, for want of a horse the man was lost."

Nearly all the infinite variety of articles in an ironmonger's shop are made by machinery. Without machinery they could not be made at all, or they would be sold at a price which would prevent them being commonly used. With machinery, their manufacture employs large numbers of artisans, who would be otherwise unemployed. There are hundreds of ingenious men at Birmingham, who go into business with a capital acquired by their savings as workmen, for the purpose of manufacturing some one single article used in finishing a house, such as the knob of a lock. All the heavy work of their trade is done by machinery. The cheapness of the article creates workmen; and the savings of the workmen accumulate capital to be expended in larger works, and to employ more workmen.

The furniture of a house some may say—the chairs, and tables, and bedsteads—is made nearly altogether by hand. True. But tools are machines; and further, we owe it to what men generally call machinery, that such furniture, even in the house of a very poor man, is more tasteful in its construction, and of finer material, than that possessed by a nobleman a hundred years ago. How is this? Machinery (that is ships) has brought us much finer woods than we grow ourselves; and other machinery (the sawing-mill) has taught us how to render that fine wood very cheap,

by economizing the use of it. At a veneering-mill, that is, a mill which cuts a mahogany log into thin plates, much more delicately and truly, and in infinitely less time, than they could be cut by the hand, two hundred and forty square feet of mahogany are cut by one circular saw in an hour. A veneer, or thin plate, is cut off a piece of mahogany, six feet six inches long, by twelve inches wide, in twenty-five seconds. What is the consequence of this? A mahogany table is made almost as cheap as a deal one; and thus the humblest family in England may have some article of mahogany, if it be only a tea-caddy. And let it not be said that deal furniture would afford as much happiness; for, a desire for comfort, and even for some degree of elegance, gives a refinement to the character, and, in a certain degree, raises our self-respect. Diogenes, who is said to have lived in a tub, was a great philosopher; but it is not necessary to live in a tub to be wise and virtuous. Nor is that the likeliest plan for becoming so. The probability is, that a man will be more wise and virtuous, in proportion as he strives to surround himself with the comforts and decent ornaments of his station.

We think that, with regard to buildings, and the furniture of buildings, you will admit that machinery, in the largest sense of the word, has increased the means of every man, to procure shelter from the elements, and to give him a multitude of conveniences within that shelter. You will also agree, we think,

that a greater number of persons are profitably employed in affording this shelter and these conveniencces, with tools and machines, than if they possessed no such mechanical aids to their industry. When the account of the population of Great Britain was last taken, in 1821, there were two millions four hundred and thirty thousand houses inhabited, and twenty-one thousand houses being built. In New Zealand, which is as large as Great Britain, there are not ten thousand habitations; and these huts are made of the roughest materials, and in the most comfortless manner. The nation which has mechanical knowledge has two hundred and fifty times as many houses as the nation without these aids; and the poorest house of the civilized people is fifty times as commodious as the finest house of the uncivilized people. You cannot doubt which nation has the most employment for builders.*

CHAPTER XII.

We have seen what machinery will do, in working up valuable materials, such as cotton, brought at a large cost from foreign countries, so as to sell the manufactured goods at a rate which does not exclude even the poorest from their purchase. Let us see what the same sort of mechanical ingenuity can effect, in

* See Appendix, No. VII. p. 214.

producing the most useful and ornamental articles of domestic life, from the common earth which may be had for digging. Without chemical and mechanical skill, we should neither have glass nor pottery; and without these articles, how much lowered beneath his present station, in point of comfort and convenience, would be the humblest peasant in the land!

The cost of GLASS is almost wholly the wages of labor, as the materials are very abundant, and may be said to cost almost nothing; and glass is much more easily worked than any other substance.

Hard and brittle as it is, it has only to be heated, and any form that the workman pleases may be given to it. It melts: but when so hot as to be more susceptible of form than wax, or clay, or any thing else that we are acquainted with, it still retains a degree of toughness and capability of extension, superior to that of many solids, and of every liquid; when it has become red-hot, all its brittleness is gone, and a man may do with it just as he pleases. He may press it into a mould; he may take a lump of it upon the end of an iron tube, and, by blowing into the tube with his mouth, (keeping the glass hot all the time,) he may swell it out into a hollow ball. He may mould that ball into a bottle; he may draw it out lengthways into a pipe; he may cut it open into a cup; he may open it with shears, whirl it round with the edge in the fire, and thus make it into a circular plate. He may

also roll it out into sheets, and spin it into threads as fine as a cobweb. In short, so that he keeps it hot, and away from substances by which it may be destroyed, he can do with it just as he pleases. All this, too, may be done, and is done with large quantities every day, in less time than any one would take to give an account of it. In the time that the readiest speaker and clearest describer were telling how one quart bottle is made, an ordinary set of workmen would make some dozens of bottles.

But though the materials of glass are among the cheapest of all materials, and the substance the most obedient to the hand of the workman, there is a great deal of knowledge necessary before glass can be made. It can be made profitably only at large manufactories, and those manufactories must be kept constantly at work night and day.

Glass does not exist in a natural form in many places. The sight of native crystal, probably, led men to think originally of producing a similar substance by art. The fabrication of glass is of high antiquity. The historians of China, Japan, and Tartary, speak of glass manufactories existing there more than two thousand years ago. An Egyptian mummy two or three thousand years old, which was lately exhibited in London, was ornamented with little fragments of colored glass. The writings of Seneca, a Roman author who lived about the time of our Savior, and of St. Jerome, who lived five hundred years after

wards, speak of glass being used in windows. It is recorded that the prior of the convent of Weymouth in Dorsetshire, in the year 674, sent for French workmen to glaze the windows of his chapel. In the twelfth century the art of making glass was known in this country. Yet it is very doubtful, whether glass was employed in windows excepting those of churches, and the houses of the very rich, for several centuries afterwards; and it is quite certain that the period is comparatively recent when glass windows were used for excluding cold and admitting light in the houses of the great body of the people, or that glass vessels were to be found amongst their ordinary conveniences. The manufacture of glass in England now employs about forty thousand people, because the article, being cheap, is of universal use.

Machinery, as we commonly understand the term, is not much employed in the manufacture of glass; but chemistry, which saves as much labor as machinery, and performs work which no machinery could accomplish, is very largely employed. The materials of which glass is made are, sand or earth, and vegetable matter, such as kelp or burnt sea-weed. These materials are put in a state of fusion by the heat of an immense furnace. It requires a red heat of sixty hours to prepare the material of a common bottle. Nearly all glass, except glass for mirrors, is what is called blown. The machinery is very simple, consisting only of an iron pipe, and the lungs of the workman; and the process is perfected in all its stages by

great subdivision of labor, producing extreme neatness and quickness in all persons employed in it. For instance, a wine glass is made thus;—One man (the blower) takes up the proper quantity of glass on his pipe, and blows it to the size wanted for the bowl; then he whirls it round on a reel, and draws out the stalk. Another man (the footer) blows a smaller and thicker ball; sticks it to the end of the stalk of the blower's glass, and breaks his pipe from it. The blower opens that ball, and whirls the whole round till the foot is formed. Then a boy dips a small rod in the glass-pot, and sticks it to the very centre of the foot. The blower, still turning the glass round, takes a bit of iron, wets it in his mouth, and touches the ball at the place where he wishes the mouth of the glass to be. The glass separates, and the boy takes it to the finisher, who turns the mouth of it; and by a peculiar swing that he gives it round his head, makes it perfectly circular, at the same time it is so hardened as to be easily snapped from the rod. Lastly the boy takes it on a forked iron to the annealing furnace, where it is cooled gradually.

All these operations require the greatest nicety in the workmen; and would take a long time in the performance, and not be very neatly done after all, if they were all done by one man. But the quickness with which they are done by the division of labor is perfectly wonderful.

The cheapness of glass for common use,

which cheapness is produced by chemical knowledge, and the division of labor, has set the ingenuity of man to work to give greater beauty to glass as an article of luxury. The employment of sharp-grinding wheels, put in motion by a treadle, and used in conjunction with a very nice hand, produces *cut* glass. Cut glass is now comparatively so cheap, that scarce a family of the middle ranks is without some beautiful article of this manufacture. And yet, cheap as glass is, a great deal of even its present price is *tax*.

If, to increase the mere labor of the glass-blowers, it was resolved that furnaces of less power should be employed, or if, for the same purpose, the subdivision of labor were abolished, and one man were to make a wine glass in all its stages, the working men of England would have no glass in their windows. If the glass-cutters were to lay down their wheels, and take to files,.the tradesman would have no cut-glass decanter on his table. The rich only would possess cut-glass vessels of any beauty of construction; and, consequently, the glass-cutters would dwindle down from thousands to hundreds, and even to tens.

There are two kinds of POTTERY. Common potters' ware, and porcelain of China. The first is a pure kind of brick; and the second a mixture of very fine brick and glass. Almost all nations have some knowledge of pottery; and those of the very hot countries are sometimes satisfied with dishes formed by their

fingers, without any tool, and dried by the heat of the sun. In England, pottery of every sort, and in all countries, good pottery, must be baked or burnt in a kiln of some kind or other.

Vessels for holding meat and drink are almost as indispensable as the meat and drink themselves; and the two qualities in them that are most valuable, are, that they shall be cheap, and easily cleaned. Pottery, as it is now produced in England, possesses both of these qualities in the very highest degree. A white bason, having all the useful properties of the most costly vessels, may be purchased for twopence at the door of any cottage in England. There are very few substances used in human food that have any effect upon these vessels; and it is only rinsing them in hot water, and wiping them with a cloth, and they are clean.

The making of an earthen bowl would be to a man who made a first attempt, no easy matter. Let us see how it is done so that it can be carried two or three hundred miles and sold for twopence, leaving a profit to the maker, and the wholesale and retail dealer.

The common pottery is made of pure clay and pure flint. The flint is found only in the chalk counties, and the fine clays in Devonshire and Dorsetshire; so that the materials out of which the pottery is made have to be carried from the South of England to Staffordshire, where the potteries are situated.

The great advantage that Staffordshire possesses is abundance of coal to burn the ware

and supply the engines that grind the materials.

The clay is worked in water by various machinery till it contains no single piece large enough to be visible to the eye. It is like cream in consistence. The flints are burned. They are first ground in a mill and then worked in water in the same manner as the clay, the large pieces being returned a second time to the mill.

When both are fine enough, one part of flint is mixed with five or six of clay; the whole is worked to a paste, after which it is kneaded either by the hands or a machine; and when the kneading is completed it is ready for the potter.

He has a little wheel which lies horizontally. He lays a portion of clay on the centre of the wheel, puts one hand, or finger if the vessel is to be a small one, in the middle, and his other hand on the outside, and, as the wheel turns rapidly round, draws up a hollow vessel in an instant. With his hands, or with very simple tools, he brings it to the shape he wishes, cuts it from the wheel with a wire, and a boy carries it off. The potter makes vessel after vessel, as fast as they can be carried away.

They are partially dried; after which they are turned on a lathe and smoothed with a wet sponge when necessary.

Only round vessels can be made on the wheel; those of other shapes are made in moulds of plaster.

Handles and other solid parts are pressed in moulds, and stuck on while they and the vessels are still wet.

The vessels thus formed are first dried in a stove, and, when dry, burnt in a kiln. They are in this state called biscuit. If they are finished white, they are glazed by another process. If they are figured, the patterns are engraved on copper, and printed on coarse paper rubbed with soft soap. The ink is made of some color that will stand the fire, ground with earthy matter. These patterns are moistened, and applied to the porous biscuit, which absorbs the color, and the paper is washed off, leaving the pattern on the biscuit.

The employment of machinery to do all the heavy part of the work, the division of labor, by which each workman acquires wonderful dexterity in his department, and the conducting of the whole upon a large scale, give bread to a vast number of people, make the pottery cheap, and enable it to be sold at a profit in almost every market in the world. It is not seventy years since the first pottery of a good quality was extensively made in England; and before that time what was used was imported, the common ware from Delf, in Holland, (from which it acquired its name,) and the porcelain from China. We now annually export thirty-eight million pieces of earthenware to all parts of the world.

CHAPTER XIII.

If the facts which we have stated in the preceding chapters have been duly consideted, it appears to us that you cannot much doubt (if you have any doubt at all) that in articles of the most absolute necessity, machinery has at the same time diminished the cost of production, and added to the numbers of the workmen. Without machinery, as we have shown, it would be impossible to raise food, to manufacture implements, to supply fuel and water, to carry on communication, to produce clothes, to build houses and furnish them, and to distribute knowledge, either *at all*, or at least at a price which should allow all men, more or less, to partake these great blessings of civilization. In the present chapter, we propose to show you some very curious effects of machinery, in the production of articles of inferior value, certainly, to those chief necessaries of life which we have mentioned; but which are in such general use amongst all of us, however trifling they may appear in themselves, that the want of them would be felt as a severe privation. Without machines they could not be made at all; or they would be made very coarsely, as mere curiosities. With machines they are made in such numbers that they constitute very large branches of trade, and give employment to hundreds of thousands of people, in assisting the machines, or in perfecting what they produce.

There is an article employed in dress, which is at once so necessary and so beautiful, that the highest lady in the land uses it, and yet so cheap, that the poorest peasant's wife is enabled to procure it. The quality of the article is as perfect as art can make it; and yet, from the enormous quantities consumed by the great mass of the people, it is made so cheap that the poor can purchase the best kind, as well as the rich. It is an article of universal use. United with machinery, many hundreds, and even thousands, are employed in making it. But if the machinery were to stop, and the article were made by human hands alone, it would become so dear, that the richest only could afford to use it; and it would become, at the same time, so rough in its appearance, that those very rich would be ashamed of using it. The article we mean is a pin.

Machinery of all kinds is difficult to be described by words. It is not necessary for us to describe the machinery used in pin-making, to make you comprehend its effects. A pin is made of brass. You have seen how metal is obtained from ore by machinery, and, therefore, we will not go over that ground. But suppose the most skilful workman has a lump of brass ready by his side, to make it into pins with common tools,—with a hammer and with a file. He beats it upon an anvil, till it becomes nearly thin enough for his purpose. A very fine hammer, and a very fine touch, must he have, to produce a pin of any sort,—even a large corking-pin! But the

pin made by machinery is a perfect cylinder. To make a metal, or even a wooden cylinder, of considerable size, with files and polishing, is an operation so difficult, that it is never attempted; but with a lathe and a sliding rest, it is done every hour, by a great many workmen. How much more difficult would it be to make a perfect cylinder, the size of a pin! A pin hammered out by hand would present a number of rough edges that would tear the clothes, as well as hold them together. It would not be much more useful or ornamental than the skewer of bone, with which the woman of the Sandwich Islands fastens her mats. But the wire of which a pin is made, acquires a perfectly cylindrical form by the simplest machinery. It is forcibly drawn through the circular holes of a steel plate; and the hole being smaller and smaller each time it is drawn through, it is at length reduced to the size required.

The head of a pin is a more difficult thing to make even than the body. It is formed of a small piece of wire twisted round so as to fit upon the other wire. It is said that by a machine, fifty thousand heads can be made in an hour. We should think that a man would be very skilful to make fifty in an hour, by hand, in the roughest manner; if so, the machine does the work of a thousand men. The machine, however, does not do all the work. The head is attached to the body of a pin by the fingers of a child, while another machine rivets it on. The operations of cut-

ting and pointing the pins are also done by machinery; and they are polished by a chemical process.

It is by these processes,—by these combinations of human labor with mechanical power,—that it occurs, that fifty pins can be bought for one half-penny, and that, therefore, four or five thousand pins may be consumed in a year by the most economical housewife, at a much less price than fifty pins of a rude make cost two or three centuries ago. A woman's allowance was formerly called her *pin-money*,—a proof that pins were a sufficiently dear article to make a large item in her expenses. If pins now were to cost a half-penny apiece, instead of being fifty for a half-penny, the greater number of females would adopt other modes of fastening their dress, which would probably be less neat and convenient than pins. No such circumstance could happen while the machinery of pin-making was in use; but if the machinery were suppressed, by any act of folly on the part of the pin-makers who work with the machinery, pins would go out of use, probably, altogether: the pin-makers would lose *all* their employment; and all the women of the land would be deprived of one of the simplest, and yet most useful inventions connected with the dress of modern times.

Needles are not so cheap as pins, because the material of which they are made is more expensive, and the processes cannot be executed so completely by machinery. But without machi-

nery, how could that most beautiful article, a *fine* needle, be sold at the rate of six for a penny? As in the case of pins, machinery is at work at the first formation of the material. Without the tilt-hammer, which beats out the bar of steel, first at the rate of ten strokes a minute, and lastly at that of five hundred, how could that bar be prepared for needle-making at any thing like a reasonable price? In all the processes of needle-making, labor is saved by contrivance and machinery. What human touch would be exquisite enough to make the eye of the finest needle, through which the most delicate silk is with difficulty passed? Needles are made in such large quantities, that it is even important to save the time of the child who lays them all one way when they are completed. Mr. Babbage, who is equally distinguished for his profound science, and his mechanical ingenuity, has described this process as an example of one of the simplest contrivances which can come under the denomination of a tool. "It is necessary to separate the needles into two parcels, in order that their points may be all in one direction. This is usually done by women and children. The needles are placed sideways in a heap, on a table, in front of each operator. From five to ten are rolled towards this person by the fore finger of the left hand; this separates them a very small space from each other, and each in its turn is pushed lengthways to the right or to the left, according as its eye is on the right or the left hand. This is the usual

process, and in it every needle passes individually under the finger of the operator. A small alteration expedites the process considerably; the child puts on the fore finger of its right hand a small cloth cap or finger stall, and rolling from the heap from six to twelve needles, it keeps them down by the fore finger of the left hand; whilst it presses the fore finger of the right hand gently against the ends of the needles, those which have their points towards the right hand stick into the finger stall; and the child removing the finger of the left hand, allows the needles sticking into the cloth to be slightly raised, and then pushes them towards the left side. Those needles which had their eyes on the right hand do not stick into the finger cover, and are pushed to the heap on the right side previous to the repetition of this process. By means of this simple contrivance, each movement of the finger, from one side to the other, carries five or six needles to their proper heap; whereas, in the former method, frequently only one was moved, and rarely more than two or three were transported at one movement to their place.

We have selected this description of a particular process in needle-making, to show that great saving of labor may be effected by what is not popularly called machinery. In modern times, wherever work is carried on upon a large scale, the division of labor is applied; by which one man attending to one thing learns to perform that one thing more

perfectly than if he had to attend to many things. He thus saves a considerable portion of the whole amount of labor. Every skilful workman has individually some mode of working peculiar to himself, by which he lessens his labor. An expert blacksmith, for instance, will not strike one blow more upon the anvil than is necessary to produce the effect he desires. A compositor, or printer who arranges the types, is a swift workman when he makes no unnecessary movement of his arm or fingers in lifting a single type into what is called his composing stick, where the types are arranged in lines. There is a very simple contrivance to lessen the labor of the compositor, by preventing him putting the type into his composing stick the wrong side outwards. It is a nick or two nicks, on the side of the type, which corresponds with the lower side of the face of the letter. By this nick or nicks he is enabled to see by one glance of his eye on which side the letter is first to be grasped, and then to be arranged. If the nick were not there he would have to look at the face of every letter before he could properly place it. Now if the printers, as a body, were to resolve to perform their work in a difficult instead of an easy way,—if they were to resolve, that the labor employed in printing were desirable to be doubled,—they might effect their unwise resolution by the simplest proceeding in the world. They might refuse to work upon types which had any nicks. In that case two compositors would certainly be

required to do the work of one; and the price of printing would consequently be greatly raised, if the compositors were paid at the present rate for their time. But would the compositors, who thus rejected one of the most obvious natural aids to their peculiar labor, be benefited by this course? No. For the price of books would rise, in the same proportion that the labor required to produce them was doubled in its quantity, by being lessened one half in its efficiency. And the price of books rising, and that rise lessening purchasers, thousands of families would be deprived of a livelihood;—not only those of compositors, but those of paper-makers, type-founders, and many other trades connected with books.

If, however, machines are bad things because they save human labor, so are all these arrangements. A manufactory, where one man does one part, and another another, is a human machine, in which one person is a wheel, another a strap, a third a lever, and so forth. If one person were to perform every operation in making a pin or needle, he could not make ten in a day—probably not one. It is said that among the early settlers of North America, there was once a whole village in which there was but one needle. If the present rage against machinery should extend to every thing which economizes human labor, (and if it is right in the one case it is equally so in the other,) an English village might be found in the same predicament.

Contrivances such as that of the needle-

sorter's sheath are constantly occurring in manufactures. The tags of laces, which are made of thin tin, are now bent into their requisite form by the same movement of the arm that cuts them. A piece of steel, adapted to the side of the shears, gives them at once their proper shape. All such ingenious applications of scientific principles lessen the price of a commodity. If the small shot which are used by sportsmen were each cast in a mould, the price would be enormous; but by pouring the melted lead, of which the shot is made, through a sort of cullender, placed at the top of a tower, high enough for the lead to cool in its passage through the air, before it reaches the ground, the shot is formed in a spherical or round shape, by the mere act of passing through the atmosphere. Some of the shots thus formed are not perfectly spherical—they are pear-shaped. If the selection of the perfect from the imperfect shots were made by the eye, or the touch, the process would be very tedious and insufficient, and the price of the article much increased. The simplest contrivance in the world divides the bad from the good. The shots are poured down an inclined plane, and, without any trouble of selection, the spherical ones run straight to the bottom, while the pear-shaped ones tumble off on one side or the other of the plane.

A vast number of people at Birmingham are employed in the manufacture of buttons; and a great variety of hands are employed in the manufacture of a single button, such as

piercers, cutters, stampers, gilders, and burnishers. Many of the operations in button-making are performed by machinery. The shanks are made by a little machine worked by a steam-engine, at the rate of fourscore a minute. But do these engines throw the button-makers out of employ? On the contrary, the cheapness with which the shank is made by the machine, instead of being expensively made by the slow labor of the hand, allows all sorts of hand-workmen to complete the rest of the button, whether in metal or glass; and thus Birmingham buttons are sold all over the world.

The manufacture of trinkets, and small articles of taste, at a cheap price by machinery, creates a demand for such articles that could never have existed at all, if they were made by hand; and therefore creates employment, which could never otherwise have existed, for very numerous workmen.

In 1824, Mr. Osler, an intelligent manufacturer at Birmingham, showed a Committee of the House of Commons an imitation, in colored glass, of an engraving on stone. "Those impressions," said he, "could not be given to real stones, but at the expense of from a guinea to thirty shillings each, if executed by a tolerable artist. We produce them for three half-pence, and the mounting of them furnishes employ to a very large number of hands indeed."

The application of machinery, or of peculiar scientific modes of working, to such apparently

trifling articles as pins, needles, buttons, and trinkets, may appear of little importance. But let it be remembered, that the manufacture of such articles furnishes employment to many thousands of our fellow-countrymen; and, enabling us to supply other nations with these products, affords us the means of receiving articles of more intrinsic value in exchange. In 1828, our exports of hardware, cutlery, and brass goods amounted to two millions sterling. No article of ready attainment, and therefore of general consumption, whether it be a laborer's spade, or a child's marble, is unimportant in a commercial point of view. The wooden figures of horses and sheep that may be bought for twopence in the toy-shops, furnish employment to cut them, during the long winter nights, to a large portion of the peasantry of the Tyrol, (an extensive district on the boundaries of Austria.) The insignificant article of the eyes of children's dolls, alone, produce, in their manufacture, a circulation of several thousand pounds. Mr. Osler, whose words we have just quoted, addressing a Committee of the House of Commons, upon the subject of his beads and trinkets, said,—"Eighteen years ago, on my first journey to London, a respectable-looking man in the city asked me if I could supply him with dolls' eyes; and I was foolish enough to feel half offended. I thought it derogatory to my new dignity as a manufacturer to make dolls' eyes. He took me into a room quite as wide and perhaps twice the length

of this, (one of the large rooms for Committees in the House of Commons,) and we had just room to walk between stacks, from the floor to the ceiling, of parts of dolls. He said, 'These are only the legs and arms—the trunks are below.' But I saw enough to convince me that he wanted a great many eyes; and as the article appeared quite in my own line of business, I said I would take an order by way of experiment; and he showed me several specimens. I copied the order. He ordered various quantities and of various sizes and qualities. On returning to the Tavistock Hotel, I found that the order amounted to upwards of five hundred pounds."

Mr. Osler tells this story to show the importance of trifles. The making of dolls' eyes afforded subsistence to many ingenious workmen in glass toys; and in the same way the most minute and apparently insignificant article of general use, when rendered cheap by chemical science or machinery, produces a return of many thousand pounds, and sets in motion labor and laborers. Without the science and the machinery, which render the article cheap, the laborers would have had *no* employ, for the article would not have been consumed. What a pretty article is a common tobacco-pipe, of which millions are used. It is made cheap and beautiful in a mould—a machine for copying pipes. If the pipe were made without the mould, and other contrivances, it would cost at least a shilling instead of a half-penny:—the poor man would

go without his pipe, and the pipe-maker without his employment.

CHAPTER XIV.

We exhibited to you, in the last chapter, a few examples, such as the sheath of the needle-sorter, and the nicks in the types of the compositor, of contrivances to economize labor. Such contrivances are not machinery; but they answer one of the great purposes of machinery,—that of saving time; and in the same manner they diminish the cost of production. The objections which some of you make to machinery, namely, that it diminishes the quantity of labor required, and therefore the number of laborers, applies also to these contrivances; and it applies, also, to the greater expertness of one workman as compared with the lesser expertness of another workman. There are boot-closers so skilful that they have reduced their arms to the precision of a machine. They can begin to close a boot with a thread a yard long in each hand, throw out each arm at once to the full extent of the thread, without making a second pull, and at every successive pull contract the arm so as to allow for the diminished length of the thread each time that it passes through the leather. There are not many workmen who can do this; but those whose sense of touch is deli-

cate enough are not blamed by their fellow-workmen, for doing that by one movement of the arm which other men do by two movements.

Every one of us who thinks at all is constantly endeavoring to diminish his individual labor, by the use of some little contrivance which experience has suggested. Men who carry water in buckets, in places where water is scarce, put a circular piece of wood to float on the water, which prevents its spilling, and consequently lessens the labor. A boy who makes paper bags, in a grocer's shop, so arranges them that he pastes the edges of twenty at a time, to diminish the labor. The porters of Amsterdam, who draw heavy goods upon a sort of sledge, every now and then throw a greased rope under the sledge, to diminish its friction, and therefore to lessen the labor of dragging it. Other porters, in the same city, have a little barrel containing water, attached to each side of the sledge, out of which the water slowly drips, like the water upon a stone-cutter's saw, to diminish the friction. The dippers of candles have made several improvements in their art within the last twenty years for the purpose of diminishing labor. They used to hold the rods between their fingers, dipping three at a time; they next connected six or eight rods together by a piece of wood at each end, having holes to receive the rods; and they now suspend the rods so arranged upon a sort of balance, rising and falling with a

pulley and a weight, so as to relieve the arms of the workman almost entirely, while the work is done more quickly, and with more precision. Are there fewer candle-makers, think you, employed now, than when they dipped only three rods, with considerable fatigue, and no little pain, as the candles grew heavy? The excise returns show that seventy-eight millions of pounds of candles were used in 1818, and one hundred and ten millions of pounds in 1829. There can be no doubt that we have more candle-makers, because candles are cheaper.

In the domestic arrangements of a well-regulated household, whether of a poor man or of a rich man, one of the chief cares is, to save labor. Every contrivance to save labor that ingenuity can suggest, is eagerly adopted when a country becomes highly civilized. In former times, in our own country, when such contrivances were little known, and materials as well as time were consequently wasted in every direction, a great Baron was surrounded with a hundred menial servants; but he had certainly less real and useful labor performed for him, than a tradesman of the present day obtains from three servants. Are there fewer servants now employed than in those times of barbarous state? Certainly not. The middle classes amongst us can get a great deal done for them in the way of domestic service, at a small expense; because servants are assisted by an infinite number of contrivances which do much of the work for them. The contrivances

render the article of service cheaper; and therefore there are more servants. The work being done by fewer servants, in consequence of the contrivances, the servants themselves are better paid than if there was no cost saved by the contrivances.

The common jack, by which meat is roasted, is described by Mr. Babbage as "a contrivance to enable the cook in a few minutes to exert a force (in winding up the jack) which the machine retails out during the succeeding hour in turning the loaded spit, thus enabling her to bestow her undivided attention on her other duties." We have seen, twenty years ago, in farm-houses, a man employed to turn a spit with a handle; dogs have been used to run in a wheel for the same purpose, and hence a particular breed so used are called "turnspits." When some ingenious servant-girl discovered that if she put a skewer through the meat and hung it before the fire by a skein of worsted, it would turn with very little attention, she made an approach to the principle of the bottle-jack. All these contrivances diminish labor, and insure regularity of movement;—and therefore they are valuable contrivances.

A bell which is pulled in one room and rings in another, and which therefore establishes a ready communication between the most distant parts of a house, is a contrivance to save labor. In a large family, the total want of bells would add a fourth at least to the abor of servants. Where three servants are

kept now, four servants would be required to be kept then. Would the destruction of all the bells therefore add one-fourth to the demand for servants? Certainly not.—The funds employed in paying for service would not be increased a single farthing; and, therefore, by the destruction of bells, all the families of the kingdom would have some work left undone, to make up for the additional labor required through the want of this useful contrivance: or all the servants in the kingdom would be more hardly worked,—would have to work sixteen hours a day instead of twelve.

In some parts of India, the natives have a very rude contrivance to mark the progress of time. A thin metal cup, with a small hole in its bottom, is put to float in a vessel of water; and as the water rises through the hole, the cup sinks in a given time—in 24 minutes. A servant is set to watch the sinking of the cup, and when this happens, he strikes upon a bell. Half a century ago, almost every cottage in England had its hour-glass—an imperfect instrument for registering the progress of time, because it only indicated its course between hour and hour; and an instrument which required a very watchful attention, and some labor, to be of any use at all. The universal use of watches or clocks, in India, would wholly displace the labor of the servants, who note the progress of time by the filling of the cup; and the same cause has displaced,

amongst us, the equally unprofitable labor employed in turning the hour-glass, and watching its movement. Almost every house in England has now a clock or watch of some sort; and every house in India would have the same, if the natives were more enlightened, and were not engaged in so many modes of unprofitable labor to keep them poor. His profitable labor has given the English mechanic the means of getting a watch. Machinery, used in every possible way, has made this watch cheap. The labor formerly employed in turning the hour-glass, or in running to look at the church clock, is transferred to the making of watches. The user of the watch obtains an accurate register of time, which teaches him to know the value of that most precious possession, and to economize it; and the producers of the watch have abundant employment in the universal demand for this valuable machine.

A watch or clock is an instrument for assisting an operation of the mind. Without some instrument for registering time, the mind could very imperfectly attain the end which the watch attains, not requiring any mental labor. The observation of the progress of time, by the situation of the sun in the day, or of particular stars at night, is a labor requiring great attention, and various sorts of accurate knowledge. It is therefore never attempted, except when men have no machines for registering time. In the same

manner the labors of the mind have been saved, in a thousand ways, by other contrivances of science.

The foot-rule of the carpenter not only gives him the standard of a foot measure, which he could not exactly ascertain by any experience, or any mental process; but it is also a scale of the proportions of an inch, or several inches, to a foot, and of the parts of an inch to an inch. What a quantity of calculations, and of dividing by compasses, does this little instrument save the carpenter; besides insuring a much greater degree of accuracy in all his operations! The common rules of arithmetic, which almost every boy in England now learns, are parts of a great invention for saving mental labor. The higher branches of mathematics, of which science arithmetic is a portion, are also inventions for saving labor, and for doing what could never be done without these inventions. There are instruments, and very curious ones, for lessening the labor of all arithmetical calculations; and tables, that is, the results of certain calculations, which are of practical use, are constructed for the same purpose. When you buy a joint of meat, you often see the butcher turn to a little book, before he tells you how much a certain number of pounds and ounces amounts to, at a certain price per pound. This book is his "Ready Reckoner," and a very useful book it is to him; for it enables him to dispatch his customers in half the time that he would otherwise require, and thus to save himself a great deal of

labor, and a great deal of inaccuracy. The inventions for saving mental labor, in calculations of arithmetic, have been carried so far, that Mr. Babbage, a gentleman whose name we have twice before mentioned, has almost perfected a calculating machine, which not only does its work of calculation without the possibility of error, but absolutely arranges printing types of figures, in a frame, so that no error can be produced in copying the calculations, before they are printed. We mention this curious machine, to show how far science may go in diminishing mental labor, and insuring accuracy.

To all of you who read this book it is no difficulty to count a hundred; and most of you know the relation which a hundred bears to a thousand, and a thousand bears to a million. Many of you are able, also, to read off those numbers, or parts of those numbers, when you see them marked down in figures. There are many uncivilized people in the world who cannot count twenty. They have no idea whatever of numbers, beyond perhaps as far as the number of their fingers, or their fingers and their toes. How have we obtained this great superiority over these poor savages? Because science has been at work, for many centuries, to diminish the amount of our mental labor, by teaching us the easiest modes of calculation. And how did we learn these modes? We learnt them from our school-masters.

If any of you follow up the false reasoning which has led you to think that whatever

diminishes labor diminishes the number of laborers, you might conclude, that, as there is less mental work to be done, because science has diminished the labor of that work, there would, therefore, be fewer mental workmen. Thank God, the greater facilities that have been given to the cultivation of the mind, the greater is the number of those who exert themselves in that cultivation. The effects of saving unprofitable labor are the same in all cases. The use of machinery in aid of *bodily* labor has set that bodily labor to a thousand new employments; and has raised the character of the employments, by transferring the lowest of the drudgery to wheels and pistons. The use of science in the assistance of *mental* labor has conducted that labor to infinitely more numerous fields of exertion; and has elevated all intellectual pursuits, by making their commoner processes the play of childhood, instead of the toil of manhood.

CHAPTER XV.

You cannot doubt, we should imagine, that any invention which gives assistance to the thinking powers of mankind, and, therefore, by dispensing with much mental drudgery, leads the mind forward to nobler exertions, is a benefit to all. It is not more than four

hundred years ago, that the use of Arabic numerals, or figures, began to be generally known in this country. The first date in those numerals said to exist in England, is upon a brass plate in Ware church, 1454. The same date in Roman numerals, which were in use before the Arabic ones, would be expressed by eight letters, MCCCCLIV. The introduction of figures, therefore, was an immense saving of time in the commonest operations of arithmetic. How puzzled you would be, and what a quantity of labor you would lose, if you were compelled to reckon your earnings and your marketings by the long mode of notation, instead of the short one! You read this book easily, because it is written in words composed of twenty-four letters. In China, where there are no letters in use, every word in the language is expressed by a different character. Few people in China write or read; and those who do, acquire very little knowledge, except the mere knowledge of writing and reading. All the time of their learned men is occupied in acquiring the means of knowledge, and not knowledge itself; and the bulk of the people get very little knowledge at all. It would be just the same thing if there were no machines or engines for diminishing manual labor. Those who had any property would occupy all their time, and the time of their immediate dependants, in raising food and making clothes for themselves, and the rest of the people would go without any food or clothes at all; or rather, which comes to the same thing,

there would be *no* "rest of the people;" the lord and his vassals would have all the produce; —there would be half a million of people in England instead of fifteen millions.

When a boy has got hold of what we call the rudiments of learning, he has possessed himself of the most useful tools and machines which exist in the world. He has obtained the means of doing that with extreme ease, which, without these tools, is done only with extreme labor. He has earned the time which, if rightly employed, will elevate his mind, and therefore improve his condition. Just so is it with all tools and machines for diminishing bodily exertion. They give us the means of doing that with comparative ease, which, without them, can only be done with extreme drudgery. They set at liberty a great quantity of mere animal power, which, having then leisure to unite with mental power, produces ingenious and skilful workmen in every trade. But they do more than this. They diminish human suffering—they improve the health—they increase the term of life—they render all occupations less painful and laborious;—and, by doing all this, they elevate man in the scale of existence.

The present Pasha, or chief ruler of Egypt, in one of those fits of caprice which it is the nature of tyrants to exhibit, ordered, a few years ago, that the male population of a district should be set to clear out one of the ancient canals which was then filled up with mud. The people had no tools, and the

Pasha gave them no tools; but the work was required to be done. So to work the poor wretches went, to the number of fifty thousand. They had to plunge up to their necks in the filthiest slime, and to bale it out with their hands, and their hands alone. They were fed, it is true, during the operation; but their food was of a quality proportioned to the little *profitable* labor which they performed. They were fed on horse-beans and water. In the course of one year, more than thirty thousand of these unhappy people perished. If the tyrant, instead of giving labor to fifty thousand people, had possessed the means of setting up steam-engines to pump out the water, and scoop out the mud,—if he had even provided the pump, which is called Archimedes' screw, and was invented by that philosopher for the very purpose of draining land in Egypt,—if the people had even had scoops and shovels, instead of being degraded, like beasts, to the employment of their unassisted hands,—the work might have been done at a fiftieth of the cost, even of the miserable pittance of horse-beans and water; and the money that was saved by the tools and machines, might have gone to furnish *profitable* labor to the thousands who perished amidst the misery and degradation of their *unprofitable* labor.

You say, probably, that this is a case which does not apply to you; because you are free men, and cannot be compelled to perish, up to your necks in mud, upon a pittance of

horse-beans, doled out by a tyrant. Exactly so. But what has made you free? Knowledge. Knowledge,—which, in raising the moral and intellectual character of every Englishman, has raised up barriers to oppression which no power can ever break down. Knowledge,—which has set ingenious men thinking in every way how to increase the profitable labor of the nation, and therefore to increase the comforts of every man in the nation. Is it for the working-men of this country, or for any other class of men, to say that knowledge shall stop at a certain point, and shall go no farther?—Is it for them to say, that although they are willing to retain the infinite blessings which knowledge has bestowed upon them—the improved food, the abundant fuel and water, the cheap clothing, the convenient houses, the drainage and ventilation which make houses healthful, the preservation of life by medical science, and the profit and comfort of books—that we are to rest satisfied with what we have got; or rather, if the destroyers of machinery are to be heard, that we are to go back to what we were five hundred years ago? Depend upon it, if we once begin to march backwards, however slow may be the first steps, the retreat towards ignorance, instead of the advance towards knowledge, will soon become pretty quick; till at last there would be one mad rush from civilization to *un*civilization. Then comes the labor of the despot, who has been comparatively idle while knowledge was laboring. There is no halting-place

then; and the mud and horse-beans of the Pasha of Egypt will be the natural end, and the fit reward, of such monstrous folly and wickedness.

No one, we suppose, desires to be sick instead of in health, to live a short life instead of a long one. The people of England have gone on increasing very rapidly, during the last fifty years; and the average length of life has also gone on increasing in the same remarkable manner, and appears still to be increasing.* Men who have attended to subjects of political economy have always been desirous to procure accurate returns of the average duration of life at particular places, and they could pretty well estimate the condition of the people from these returns. Savages, it is well known, are not long livers; that is, although there may be a few old people, the majority of savages die very young. Why is this? Many of the savage nations that we know have much finer climates than our own; but then, on the other hand, they sustain privations which the poorest man amongst us never feels. Their supply of food is uncertain, they want clothing, they are badly sheltered from the weather, or not sheltered at all, they undergo very severe labor when they are laboring. From all these causes savages die young. Is it not reasonable, therefore, to infer that if in any particular country the average duration of life goes on increasing; that is, if fewer people, in a given number and a given time, die now than for-

* See Appendix, No. II. p. 207.

merly, the condition of that people is improved; that they have more of the necessaries and comforts of life, and labor less severely to procure them? Now let us see how the people of England stand in this respect. The average mortality in a year about a century ago was reckoned to be one in thirty; fifty years ago it was one in forty; thirty years ago one in forty-seven, twenty years ago one in fifty-two; and now it is one in fifty-eight. You see, therefore, according to this estimate, of which there is no reason whatever to doubt the accuracy, that where one person dies in a year now, two died, a century ago. This remarkable result is, doubtless, produced in some degree by improvements in the science of medicine, and particularly by the use of inoculation for the small-pox, and vaccination. But making every allowance for these benefits, the fact furnishes the most undeniable truth, that the people of England are infinitely better fed, clothed, and lodged than they were a century ago, and that the labor which they perform is infinitely less severe.

The effect of continued violent bodily exertion upon the duration of life might be illustrated by many instances; we shall mention one. The late Mr. Edgeworth, in his Memoirs, repeatedly speaks of a boatman whom he knew at Lyons, as an old man. "His hair," says Mr. Edgeworth, "was gray, his face wrinkled, his back bent, and all his limbs and features had the appearance of those of a man of sixty; yet his real age was but twenty-

seven years. He told me that he was the oldest boatman on the Rhone, that his younger brothers had been worn out before they were twenty-five years old; such were the effects of the hardships to which they were subject from the nature of their employment." That employment was, by intense bodily exertion, and with the daily chance of being upset, to pull a boat across one of the most rapid rivers in the world,—

"The swift and arrowy Rhone,"

as one of our poets calls it. How much happier would these boatmen have been during their lives, and how much longer would they have lived, could their labor have been relieved by some mechanical contrivance! and without doubt, the same contrivance would have doubled the number of the boatmen, by causing the passage to be more used. As it was, they were few in number, they lived only a few years, and the only gratification of those few years was an inordinate stimulus of brandy. This is the case in all trades where immense efforts of bodily power are required. The exertion itself wears out the people, and the dram, which gives a momentary impulse to the exertion, wears them out still more. The coal-heavers of London, healthy as they look, are but a short-lived people. The heavy loads which they carry, and the quantity of liquor which they drink, both together make sad havoc with them.

Violent bodily labor, in which the muscu-

lar power of the body is unequally applied, generally produces some peculiar disease. Nearly all the pressmen who were accustomed to print newspapers, of a large size, by hand, were ruptured. A great number of the annuitants of the Printer's Pension Society are ruptured pressmen, whose muscles have been unequally strained by their laborious operation. The printing-machine now does the same description of work.

What is the effect upon the condition of pressmen generally by the introduction of the printing-machine to do the heaviest labor of printing? That the trade of a pressman is daily becoming one more of *skill* than of *drudgery*. At the same time that the printing-machine was invented, one of the principles of that machine—that of inking the types with a roller instead of two large cushions, called balls, was introduced into hand printing. The pressmen were delighted with this improvement. "Ay," said they, "this saves our labor; we are relieved from the hard work of distributing the ink upon the balls. What the roller did for the individual pressman, the machine, which can only be beneficially applied to rapid and to very heavy printing, does for the great body of pressmen. It removes a certain portion of the drudgery, which degraded the occupation, and rendered it painful and injurious to health. We have seen two pressmen working a daily paper against time; it was always necessary, before the introduction of the machines, to put an immense

quantity of bodily energy into the labor of working a newspaper, that it might be published at the proper hour. Time, in this case, was driving the pressmen as fast as the rapid stream drove the boatmen of the Rhone; and the speed with which they worked was killing them as quickly.

If artisans, who have generally the means of acquiring knowledge, were to think as they ought to do upon the benefits to their own particular trade of machines for saving labor, we should never hear of combinations against such machines. A reflecting being feels it a degradation to be employed in *unprofitable* labor. Some parishes, we understand, set their paupers to turn a grindstone, upon which nothing is ground; and, to their honor be it spoken, the poor people, in many cases, would rather starve than submit to this ignoble occupation. Even the unhappy persons at treadmills feel additionally degraded when they turn the wheels without an object; they call it "grinding the wind." Why are these people degraded by such occupations? Why do they consider their labor ignominious? Because their labor has no results. Is it not equally ignominious when men resolve, by suppressing machinery, to do that with a great deal of labor, which would otherwise be done by a very little labor? to bind themselves to the wheel, when the wheel would do the work without them?—to labor, in fact, without results from their labor.

We have a remarkable example of the folly

of a particular body of men upon this subject now lying before us. We have a paper, dated the 16th of December, 1830, issued by nearly five hundred journeymen bookbinders of London and Westminster, calling upon their employers to give up the use of a machine for *beating* books. Books, before they are bound in leather, were beat with large hammers upon a stone, to make them solid. That work is now done in London by a machine. The workman is relieved from the only portion of his employ which was sheer drudgery—from the only portion of his employ which was so laborious, that it rendered him unfit for the more delicate operations of bookbinding, which is altogether an art. The greatest blessing ever conferred upon bookbinders, as a body, was the invention of this machine. Why? It has set at liberty a quantity of mere labor without skill to furnish wages to laborers with skill. The master bookbinders of London and Westminster state that they cannot find good workmen in sufficient quantities to do the work which the consumer requires. The good workmen and the bad were each employed in the drudgery of beating, which called into action a certain muscular power of the arm and hand, which unfitted them for the delicacy and rapidity of other operations of bookbinding. The good workmen were therefore lessened by the drudgery of the beating hammer; but the bad workmen, the mere laborers, whose work a very simple machine can do better, feel that they cannot

compete with this machine. Why? They were indolent and dissipated, and the work which they neglected is now done without their aid. The great delay in bookbinding was always occasioned by the delay in beating. It was a mere drudgery which the better men paid others to perform; and these mere drudges, by the neglect of their work, kept the higher orders of bookbinders idle. And yet, in spite of their own experience, all the bookbinders try to put down the beating-machine, which, in truth, has a tendency, above all other things, to elevate their trade, and to make that an art which in one division of it was a mere labor. If the painter were compelled to grind his own colors and make his own frames, he would no longer follow an art, but a trade; and he would receive the wages of a laborer instead of the wages of an artist, not only so far as related to the grinding and frame-making, but as affecting all his occupations, by the drudgery attending a portion of them.

CHAPTER XVI.

THE objection of the bookbinders to the beating-machine, offers a remarkable example of the inconsistency of all such objections. The bookbinders have a machine called a plow, for cutting the edges of books, which is, probably, as old as the trade itself. A great deal of labor and a great deal of material are saved by this plow. Why do they not require that a book should be cut with a ruler and a pen-knife? They have

presses, too, acting with a screw, to make the book solid and flat. A press with an iron screw will do ten times the work of a press with a wooden screw; and one of Bramah's hydraulic presses, which has power enough, if fully exerted, to break a piece of wrought iron three inches thick, will do twenty times the work of the common iron-screw press. Nobody insists that the master bookbinder shall use the press of the smallest power, that he may be compelled, at the same time, to use the labor of ten men instead of one. The objection would be too absurd upon the face of it. But a press of any kind is an *old* machine. A machine for beating books is a *new* machine. Working-men, and other men who ought to know better, have attempted to draw distinctions between old machines and new machines. As it is, the inventors of machines generally go before their age; and thus too many of them have either starved or struggled for years with want, because their own generation was not wise enough to value the blessings which science and skill had provided for it. But if the ordinary difficulties of establishing a new invention, however valuable it might prove, were to be increased by the folly which should say, we will have no new machines at all, or at any rate, a machine shall become old before we will use it, there would be an end to invention altogether.

We have before us, "A List of Inventions of the various kinds of Machinery made use of in the manufacture of Hosiery, Lace, &c." The

compiler of the List, which is printed at Nottingham, mentions these various kinds of machinery as having been "the means of raising the mechanics of Nottingham to so high a rank amongst the artisans of Great Britain." This List contains a brief description, with the dates of the invention, and the names of the inventors, of no less than one hundred and one machines, nearly all applied to the manufacture of stockings and lace. Many of these machines are now in use; some of them are disused; but they are all improvements, or attempted improvements, of some less perfect machines which preceded them. Before the invention of the first stocking-machine, in the year 1589, by William Lea, a clergyman, none but the very rich wore stockings, and many of the most wealthy went without stockings at all, their hose being sown together by the tailor, or their legs being covered with bandages of cloth. William Lea made a pair of stockings, by the frame, in the presence of King James I.; but such was the prejudice of those times, that he could get no encouragement for his invention. His invention was discountenanced, upon the plea that it would deprive the industrious poor of their subsistence. He went to France, where he met with no better success; and died at last of a broken heart. The great then *could* discountenance an invention, because its application was limited to themselves. *They* only wore stockings: the poor who made them had none to wear. Stockings were not cheap enough for

the poor to wear, and therefore they went without. Of the millions of people now in this country, how few are without stockings! What a miserable exception to the comfort of the rest of the people does it appear to you, when you see a beggar in the streets without stockings! You consider such a person to be in the lowest stages of want and suffering. Two centuries ago, not one person in a thousand wore stockings;—one century ago, not one person in five hundred wore them;—now, not one person in a thousand is without them. Who made this great change in the condition of the people of England, and, indeed, of the people of almost all civilized countries? William Lea—who died at Paris of a broken heart. And why did he die of grief and penury? Because the people of his own days were too ignorant to accept the blessings he had prepared for them.

We ask with confidence, had the terror of the stocking-frame any real foundation? Were any people thrown out of employment by the stocking-frame?

> "The knitters in the sun,
> And the free maids who weave their thread with bones,"

as Shakspeare describes the country lasses of his day, had to *change* their employment; but there was infinitely more employment for the makers of stockings, for then every one began to wear stockings. The improvements of machinery have made cotton and worsted stockings so exceedingly cheap, that it is almost become a question, whether it is worth while

to mend stockings. What is the consequence? In Nottingham and Derby, the great stocking counties, there are thousands and tens of thousands of persons engaged in the manufacture. In almost every cottage you hear a stocking-frame at work. It is the same with lace-making. The invention of the lace-machine is comparatively a recent one; and the machine which makes the net of considerable breadth, has been invented within these twenty years. Every body now wears lace, and therefore the making of lace has become a most extensive manufacture, instead of a very small one. The manufacture employs many persons with the machine, in the place of very few without the machine, because the consumers of lace can buy the article at a small price instead of a large one. But the makers of lace by the pillow are thrown out of employment. Certainly they are, if they have not readiness enough to adapt their employment to the change. The greater number have learnt to accommodate their employment to the machine, and not to strive against it. As many young women, and doubtless many more, are now employed in working upon the lace made by the machines, as were formerly employed in making the lace itself. At Marlow, which, ten years ago, was a celebrated place for making lace by hand, the people have had the good sense to turn their attention to making children's caps instead of making lace, and the labor so engaged at the present moment, as we have ascertained from a correct inquiry

into the facts, employs no less than five hundred persons, and produces a return for the labor, independent of the materials, of five thousand pounds yearly.

Now, suppose that the ignorance and prejudice which prevailed at the time of James I. upon the subject of machinery, had continued to the present day; and that not only the first stocking-frame of William Lea had never been used, and the machine for making lace had never been invented, but that all of the hundred and one machines, employed in the manufacture of hosiery and lace, had never been thought of; and they could not have been thought of, if the first machines had been put down. The greater number of us, in that case, would have been without stockings; and the little lace that the price would have permitted to have been used, would have been brought from Flanders. Two hundred years ago, the nobility seldom put on their stockings but when they went to court; and one hundred years ago, a peeress only exhibited her lace when she displayed her diamonds.

But there would have been a greater evil than even this. We might all have found substitutes for stockings, or have gone without them; and we might have left the wearing of lace to the wearers of diamonds. But the progress of ingenuity would have been stopt. The inventive principle would have been destroyed, Society must either go forward or backward. There can be no halting-place for any long period. If we had gone backward,

we should not only have lost lace and stockings, but all the comforts—all the decencies—all the elegancies—and, worse than these losses, all the knowledge—which distinguish the civilized from the uncivilized state. The same thing would happen *now*, if the principle were admitted that new inventions, and new machines, are *evils*, and not benefits. The stocking-frame was once a *new* machine, and, therefore, the court discountenanced it. There are people at the present day as ignorant as the court was then, who would discountenance new machines, that, like the stocking-machine, will some day be *old*. An engineer, who has contributed largely to benefit society by his inventions, tells the writer of this book that he has completed several machines which he considers of general utility, but which he dares not bring forward in the present state of the popular mind. If this feeling were to prevail and to extend;—*if* the brute force which seeks to destroy machinery were not to be put down by the power of the laws, and if the unwise prejudice which desires to repress it could not be conquered by the power of reason—the glory and prosperity of this country would be gone for ever. We should have reached the end of our career of improvement. We should begin a backward race; and it would remain for the inquiring savages of such countries as New Zealand and Otaheite to march forward. The night of the dark ages would return to Europe.

Those who have not taken the trouble to

witness, or to inquire into, the processes by which they are surrounded with the conveniences and comforts of civilized life, can have no idea of the infinite variety of ways in which invention is at work to lessen the cost of production. The people of India, who spin their cotton wholly by hand, and weave their cloth in a rude loom, would doubtless be astonished when they first saw the effects of machinery, in the calico which is returned to their own shores, made from the material brought from their own shores, cheaper than they themselves could make it. But their indolent habits would not permit them to inquire how machinery produced this wonder. There are many amongst us who only know that the wool grows upon the sheep's back, and that it is converted into a coat by labor and machinery. They do not estimate the prodigious power of thought—the patient labor—the unceasing watchfulness—the frequent disappointment—the uncertain profit—which many have had to encounter in bringing this machinery to perfection. How few, even of the best informed, know that in the cotton manufacture, which, from its immense amount, possesses the means of rewarding the smallest improvement, invention has been at work, and most successfully, to make machines, that make machines, that make the cotton thread. There is a part of the machinery used in cotton-spinning called a reed. It consists of a number of pieces of wire, set side by side in a frame, resembling, as far as such things admit

of comparison, a comb with two backs. These reeds are of various lengths and degrees of fineness; but they all consist of cross pieces of wire, fastened at regular intervals between longitudinal pieces of split cane into which they are tied with waxed thread. A machine now does the work of reed-making. The materials enter the machine in the shape of two or three yards of cane, and many yards of wire and thread; and the machine cuts the wire, places each small piece with unfailing regularity between the canes, twists the thread round the cane with a knot that cannot slip, every time a piece of wire is put in, and does several yards of this extraordinary work in less time than we have taken to write the description—nearly in as little time as you can read it in. There is another machine for making a part of the machine for cotton-spinning, even more wonderful. The cotton wool is combed by circular cards of every degree of fineness; and the card-making machine, receiving only a supply of leather and wire, does its own work without the aid of hands. It punches the leather—cuts the wire—passes it through the leather—clinches it behind,—and gives it the proper form of the tooth in front,—producing a complete card of several feet in circumference in a wonderfully short time. All men feel the benefit of such inventions, because they lessen the cost of production. The necessity for them always precedes their use. There were not reed-makers and card-makers enough in England to supply the demands of

the cotton machinery; so invention went to work to see how machines could make machines; and the consequent diminished cost of machinery has diminished the price of clothing.

Machinery enters into competition with human labor; and therefore there are some people who say, let us tax machinery to support the labor which it supersedes. The real meaning of this is—let us tax machinery, to prevent cheapness of production, to discourage invention, and to interfere with a change from one mode of labor to another mode. There are temporary inconveniences, doubtless, in machinery, which we shall presently examine; and we think that every man who suffers from these inconveniences possesses in himself the power of remedying those evils, or at least of mitigating them. But it appears to us that any proposed remedy for a temporary evil, which has a tendency to arrest the course of improvement, is a little like the ancient wisdom of the Dutch market-woman, who, when the one pannier of her ass is too heavily laden with cabbages, puts a stone into the other pannier, to make matters equal.

CHAPTER XVII.

When men complain of a want of employment, they complain of the want of some

power which is not in themselves. Nobody hinders them from working: they may dig a hole and fill it up again; or they may fill a bucket from a pond, and carry the water to another pond. But they do not do these things. There was less employment amongst our ancestors—much less, than there is now; and they therefore had a proverb that it is better to play for nothing than to work for nothing—which means, that it is better not to work at all, than to do unprofitable work. What power is that which the laborer requires to set him to profitable work? It is the power of

CAPITAL.

Capital is the accumulation of the fruits of former industry. Nations which consume every thing that they produce, without leaving a store for future production, have no capital. They live, as we term it, from hand to mouth. They are poor and wretched. The accumulation of capital is one of the greatest means of multiplying the power of man. United with the power of exchange—that is the power of giving capital for labor, and the produce of capital and labor for other produce,—it constitutes, in a great degree, the superiority of our species over all other animals, and the superiority of those of our species who employ it over those who do not. The people who do not use this faculty, such as the savages of North America, are gradually disappearing from the face of the earth. They are driven out, by capital extending the dominion of industry.

The use of capital consists in its advance.

It goes before all operations of labor and trade. It is the power that sets labor and trade in motion; just as the power of wind, or water, or steam, gives movement to wheels and pistons. The distinction between the poorest man who works, and the poorer man incapable of work, is, that the one possesses capital, the other does not. The time which a lad spends in learning the most ready way to perform any labor, is his advance of capital. The thing produced by that advance is a workman. There is an accumulation of knowledge and skill, which makes the difference between the workman and the *no* workman. When a laborer, or an artisan, goes to work on Monday morning, and works all the week, receiving no wages till Saturday night, he makes a more direct advance of capital. He has either accumulated something upon which he can live during the period in which he waits for his wages; or somebody trusts him: in the one case, it is his own capital; in the other case, it is the capital of another which is advanced. The man who sells matches in the street has a capital. He has advanced something to purchase the wood and sulphur of which his matches are made, and he has advanced his time; his profit, like that of all other capitalists, depends upon the certainty and the quickness of his return. If he cannot sell his matches at all, or if he is a long time in selling them, he must live upon his other accumulations, or he must starve. The business of a matchmaker as much depends for its success upon

the right employment of capital, as that of a farmer or a cotton-manufacturer.

We will endeavor to point out, as briefly as we can, how capital operates upon the three great branches of human industry, namely, agriculture, manufactures, and commerce.

A farmer having acquired capital, either by the former savings of himself or his fathers, or by borrowing from the savings of others, takes a certain number of acres of land. He changes his capital of money into other things which are equally capital;—into horses, and cows, and sheep, and agricultural instruments, and seed. He makes an advance in the hope of producing a profit. He therefore sets his horses to work;—he gets milk from his cows; —he shears his sheep;—he fattens his oxen —and he puts his tools into the hands of laborers, to prepare the ground for the reception of his seed. He is paying money away on every side, which he would not do, if he did not expect a return, with a profit. By all these operations—by the work of his horses and his laborers—by the increase in number, and the increase in value of his flocks and herds,—and by the harvest after the seed-time,—new produce is created which produces a return of capital, and ought to produce a profit if that capital is properly expended. The hope of profit sets the capital to work, and the capital sets the laborer to work. If there were no capital there would be no labor. Capital gives the laborer the power, which he has not in himself, of working for a profit.

A capitalist desires to set up a cotton manufactory. He erects buildings, he purchases machines, he buys cotton-wool, he engages workmen. The annual value of the buildings and of the machines,—that is the interest upon their cost, added to the loss by wear and tear —the price of the raw material, and the wages of the workman, are all calculated to be paid out of the price at which the cotton thread will be sold. To engage in such large undertakings, in which the returns are slow, there must be great accumulation of capital. To engage in such large undertakings, in which the risk is considerable, there must be abundant enterprise. Without extensive accumulations of capital, which produce enterprise, they could not be engaged in at all.

Capital employed in commerce circulates through the world in a thousand forms; but it all comes back in produce to the country tha sends it out. Nations that have no accumulated stock, that is, no capital, have no commerce; and where there is no commerce there are no ships and no sailors; and there are no comforts besides those which spring up at the feet of the more fortunate individuals of such nations.*

When one country is poor, as compared with another country possessing no greater natural advantages, there can be no doubt that there are some circumstances in the government, or in the habits of the people, which have a tendency to prevent capital being

* See Appendix, No. V. p. 212.

employed in that country. There can be no doubt, for instance, that the poverty of Ireland, as compared with England, is produced by a want of capital. The evidence of Dr. Doyle, a distinguished Roman Catholic prelate, before a Committee of the House of Commons, in 1830, is conclusive upon this point, as well as upon the causes which have mainly operated to prevent capital being employed in Ireland.

"*Q.* Do you think there is the means of employing additional capital upon land, or in other improvements in Ireland, at the present moment, yielding profit not less than the average rate of profit?

A. I can have no doubt upon that subject; and I am very decidedly of opinion, that a quantity of capital might be usefully expended both in the improvement of the lands now inclosed, and in the reclaiming lands now waste.

Q. If capital can be so employed with a profit, what are the circumstances which, in your opinion, prevent it from being so employed, for if it were to be so employed naturally, it is presumed, you would prefer such a system to any forced application of capital whatever?

A. Undoubtedly I would; but it is not employed at present, because there are, or there have been, rather, in Ireland, many causes which deterred men from embarking capital in that country, which could be employed with more safety, if not with more profit, in another. Many of these causes have ceased, and therefore there is, at present, an opening for the employment of capital which

did not exist before; but notwithstanding that, I think there are still very many obstacles to the employment of it in the improvement of lands, or the establishment of manufactures in Ireland, the chief of which are the unsettled state of the population in that country, the nightly combinations and outrages which result from that state, as well as the want of character in the common people themselves. All those things operate very much to prevent the investment of capital in land in Ireland by men who, if society were better arranged, would not hesitate so to vest it. I think, therefore, that though there may be at present a prospect that capital could be employed usefully in Ireland, it would be the duty of the legislature to open that prospect wider, and to give greater facilities and encouragements to the investment of capital, to hold out inducements to men to settle in that country, by preparing for them a quiet and well-ordered population."

The causes, you see, that prevent capital being employed in Ireland, and which, therefore, preventing profitable labor, keep the people poor, are the unsettled state of the population in that country—the nightly combinations and outrages that result from that state—as well as the want of character in the working people. Whatever tends to make the state of society insecure, tends to prevent the employment of capital. In despotic countries, that insecurity is produced by the tyranny of one. In other countries, where the people

having been misgoverned, are badly educated, that insecurity is produced by the tyranny of many. In either case, the bulk of the people themselves are the first to suffer, whether by the outrages of a tyrant, or by their own outrages. They prevent labor; by driving away to other channels the funds which support labor. In such countries as Turkey, where, when a man becomes rich, his property is seized upon by the one tyrant, nobody dares to avow that he has any property. Capital is not employed; it is hidden: and the people who have capital live, not upon its profits, but by the diminution of the capital itself. It was the same in the feudal times in England, when the lord tyrannized over his vassals, and no property was safe but in the hands of the strongest. In those times, people who had treasure buried it. Who thinks of burying treasure now in England? In the plays and story-books which depict the manners of those times, we constantly read of people finding bags of money. We never find bags of money now, except when a very old hoard, hidden in some time of national trouble, comes to light.* Why is money not hidden, and not found now? Because people have security for the employment of it, and by the employment of it in creating new produce, the nation's stock of capital goes on hourly increasing.

* So little time ago as the reign of Charles II. we read of a gentleman (Secretary to the Admiralty) going down from London to his country-house, with all his money in his carriage, to bury it in his garden. See *Pepys' Memoirs*.

The great point to which we would draw your attention, from this plain statement of the use of capital is, that if any act is committed by which capital is either destroyed or placed in danger, there is an insecurity in the employment: and that, therefore, capital is first withdrawn from that employment which is most dangerous; and, secondly, from the country altogether, if all its employments become equally dangerous.

At the present moment, in many parts of this country, the farmer's property is destroyed, because the laborer thinks the farmer does not give him sufficient employment. The case is not mended by this destruction. If the farmer's property is destroyed, the funds which he possesses for paying laborers are at the same time destroyed. The capital is destroyed which gives laborers that power of laboring profitably which is not in themselves. If the farmer's property is not actually destroyed, but only placed in jeopardy, he will withdraw his capital into some other business, where the danger of destruction does not exist. If the property of the farmer is neither actually destroyed, nor placed so greatly in danger as to warrant the sacrifice consequent upon withdrawing it to another business, there will still be evil if the slightest degree of insecurity exist. There will be no *new* capital invested in the business of farming. Changes are constantly taking place in the disposal of capital, and the comparative security of its employment gives the direction

to these changes. If much capital leaves agriculture, and none comes to it, the funds for the maintenance of agricultural labor will fearfully decline. And who will be the first to suffer? The laborers themselves. The capital may be transferred to other employments, but the laborers will remain; they will perish upon the soil which they have rendered infertile.

In this country there are immense public works constantly going forward, in the prosecution of which men unite their capital for objects which are too large to be undertaken by any single man. Such associations are called companies. In this way, roads, canals, and railways are formed, docks and bridges are constructed, water-works are established, mines are worked. Such employments of capital are, more than any other, affected by the condition of a country with regard to its internal security. The people of Ireland are crying out for such uses of capital amongst them to give them labor; but they will demand the capital in vain till the capitalists feel sure that their capital will not be put in jeopardy by the violent actions of the people themselves. If combinations against machinery were to go on in England, there would be no new capital employed to give facilities to commerce and manufactures, whose prosperity is mainly the result of machinery. There would be no more capital for public works, which employ thousands of workmen in their construction. Would the

railway from Birmingham to London be proceeded with, in which a capital of three millions sterling is to be employed, if the artisans of Birmingham were to break their machines? There would be an end of the commerce of Birmingham in that case; and then the railway would be given up, for the existing canals would have no employment, and there would be no traffic on the roads. The only use of roads would be to enable the starving workmen, starved by their own folly, to wander about the country in search of that profitable labor which they had destroyed. They would wander about in vain. The capital would make itself wings and fly away to other countries, where men still acted as reasonable beings. Our capital, our machines, and our best mechanics would go to France and America. The tyranny of a mob would drive away the wealth and industry of the nation to places where they could be employed in security, just in the same way as the tyranny of a king drove the French silk and cotton weavers to this country a century and a half ago. The effects of all tyranny are the same, whether it be that of one despot or of many despots. Tyranny of any kind destroys our peace and our security. When men are in terror they try to save what they have got, instead of endeavoring to get more. Capital no longer does its work, labor is at an end.

It is easy to perceive from these facts, which cannot be denied, that if, through the prejudices of some mechanics against machinery

the capital engaged in manufactures should be rendered as insecure as the capital engaged in agriculture, that capital would go to other countries where such insecurity did not exist. The insecurity of capital employed in agriculture, and of capital employed in manufactures, would extend to capital employed in commerce; and the want of employment of capital in each of these great branches of human industry would produce a state of misery which it would be fearful to contemplate. We should all be more or less without food, without fuel, without clothes. The land would cease to produce corn, the mines would cease to produce ore, the forges would cease to produce tools, the looms would cease to produce cloth. There would be

> "No kind of traffic,
> * * * * no name of magistrate;
> Letters should not be known, no use of service,
> Of riches or of poverty; no contracts,
> Successions; bound of land, tilth, vineyard, none;
> No use of metal, corn, or wine, or oil;
> No occupation; all men idle, all,
> And women too."

The poet has well described the state of a community without industry, because without capital. It is the state of savages who bear its hardships, and who are few in number, because they are thinned by those hardships. But let a nation of twenty millions of people, by any act of folly, drive capital away from them, and famine, pestilence, civil war, midnight murder, rapine, and every other dreadful

calamity would follow this unnatural violation of the laws of God and man. The twenty millions would soon be reduced to one million; the country would fall back a thousand years. We should all be idle, but our idleness would not feed or clothe us; we might all desire to labor, but there would be no accumulation to give us profitable labor. We should all be prodigals who had spent our substance, and there would be no forgiving parent's home where our misery might be pitied and relieved when it was past endurance. The friend whom we had driven from us would never return. We could not go to the capital; the capital would not come back to us. The land would be depopulated and rendered barren; and then the few that remained would have slowly to emerge from poverty and barbarism, by going back to the arts which the world has been laboriously acquiring for hundreds of years.*

CHAPTER XVIII.

There are great temporary inconveniences in the introduction of a new machine. Who can doubt it? Who can deny that it is a serious evil, when the honest industry of a working man is suddenly invaded by a power against which he cannot struggle;—when, in fact, such a man as Joseph Foster, laborious, intelligent, reflecting, and singularly honest in the

* See Appendix, Nos. I. and II. p. 207

expression of his opinions, says, that his condition has been declining ever since the introduction of power-loom weaving;—that he has not any hope that any possible improvement in the cotton trade would provide in future for the hand-weavers out of employment;—that the well-informed weavers have a general persuasion that the hand-weaving is a business which is nearly extinct altogether. The state of change is doubtless a state of suffering. The moment the machine comes into competition with human labor, the wages of that labor begin to adjust themselves to the lesser cost of production by the machine. The Rev. Mr. Turner, (the present learned and benevolent Bishop of Calcutta) was in 1827 the rector of Wilmslowe, in Cheshire, a manufacturing parish. The questions of the same Committee that examined Joseph Foster, and Mr. Turner's answers, show how the competition of human labor is maintained against machinery, until that labor finds new objects of employment, generally created by the machines themselves:

"*Q.* How long has the hand-loom weaving been introduced in your parish?

A. I cannot speak with great certainty, but I should think, for thirty years it has been the standard occupation of our people, and it has been an occupation in which they have engaged without any limitation but the size of their families, for they had as much work as the looms they set up would enable them to furnish.

Q. Has not the invention of the power-loom superseded the use of those hand-looms?

A. Undoubtedly; it would have superseded them much more rapidly than it has done, if the hand-loom weaver were not enabled to submit to a reduction of wages.

Q. But in so submitting, he has accepted wages which are insufficient to support him, and he looks to parochial contribution for the remainder of his support?

A. Yes; and, in fact, the competition between the hand-loom and the power-loom is maintained out of the poor-rates."

Now we perceive, most clearly, that society, when such changes occur, interposes an artificial power to prevent immediate ruin from such changes. Society breaks the fall of the workman who is thrust out of his place by them. There can be no doubt that it is the duty of society to interpose, in some way or other, to prevent a general blessing from becoming a particular curse. The only question is, in what way that interposition shall be effected. The hand-loom weavers, in 1827, were desirous to emigrate. They had been struggling, and very naturally, for twenty years, to keep the less useful machine in the field against the more useful machine; and they could only maintain that struggle by a constant yielding in the price of their own labor. They at last could yield no longer; and they wisely determined to give up the struggle. They wished to change their situation altogether; to remove to new places, and

engage in new occupations: they wished to have their labor profitable instead of unprofitable. If it were within the power of a government to assist such a wish, there can be no doubt but that power would be beneficially, because humanely, employed. Of the possibility of the exercise of such a power, it is not for us to speak. It is our duty only to show, that the wish to change their employment, on the part of the hand-loom weavers, was the wisest wish they could form; a wish, the completion of which would have been as beneficial to others as to themselves.

In the consideration of the evils resulting from the introduction of a new machine, you must never forget the principle which we have sought to impress upon you throughout this book,—that the object for which machines are established, and the object which they do effect, is cheapness of production. Machines either save material, or diminish labor, or both. "Which is the cheapest," said the Committee to Joseph Foster, "a piece of goods made by a power-loom, or a piece of goods made by a hand-loom?" He answered, "a power-loom is the cheapest." What, then, is the effect of this reduced cost of production, ultimately, upon the employment of labor? That the manufacture is increased,—that more cloth is consumed,—that the consumer has more money to lay out in cloth, or more money to lay out in other things. We have shown you, most distinctly, the effect of the spinning machinery in increasing twenty-fold

the number of people engaged in that branch of manufacture. But let us put the circumstance before your eyes once more, in the words of a person old enough to recollect the precise facts connected with the first introduction of that machinery. The Committee that we have so often mentioned examined Mr. Fielden, a resident at Blackburn, upon this particular subject.

" *Q.* Do you remember what occurred in Lancashire, when spinning-factories were first established?

A. I recollect that period very well.

Q. Were not a very considerable number of persons thrown out of work, and was not there great distress, in consequence of the introduction of machinery, when spinning was done by machinery and not by hand-labor?

A. Yes, there was a great deal of distress, and much rioting took place at the time.

Q. Persons who had formerly obtained a good living by spinning by hand-labor, were unable to obtain the same wages, and in the same manner, in consequence of the introduction of spinning machinery?

A. If the description of spinning that was carried on in the neighborhood of Blackburn is alluded to, that which was done by the hand, the raw cotton was taken out by the weaver, and spun in his own house, and the change was productive of considerable inconvenience in the first instance; great alarm was created, and some spinning-wheels were destroyed at the time; many persons were

thrown out of employment; but at that time the manufacture of the kingdom was in a very limited state, compared with what it is at present.

Q. Was not the result of the introduction of that machinery an immense increase of the manufacture?

A. Very great.

Q. And more advantageous wages for a considerably increased number?

A. Yes, materially so."

It is, we think, self-evident, that if the temporary distress of the hand-spinners, which produced the rioting, and the destruction of spinning-mills here described, had gone on to prevent altogether the manufacture of cotton thread by the spinning machinery, the consumption of cotton cloth would have been little increased, and the number of persons engaged in the manufacture would have been twenty, thirty, or even forty times less than the present number. But there would have been another result. Think you that the great body of the people of Europe would have chosen to wear, for many years, *dear* cloth instead of *cheap* cloth, that a few thousand spinners might have been kept at their ancient wheels in Lancashire? Capital can easily shift its place, and invention follows where capital goes before. The people of France, and Germany, and America, would have employed the cheap machine instead of the dear one; and the people of England would have had cheap cloth instead of dear cloth from thence. We

cannot build a wall of brass round our islands; and the thin walls of prohibitive duties are very easily broken through. A profit of from twenty to thirty per cent. will pour in any given quantity of smuggled goods that a nation living under prohibitive laws can demand. Buonaparte, in the height of his power, passed the celebrated Berlin decree for the exclusion of all English produce from the continent of Europe. But our merchants laughed at him. The whole coast of France, and Holland, and Italy, became one immense receiving place for smuggled goods. If he had lined the whole coast with all the six hundred thousand soldiers that he marched to Russia, instead of a few custom-house officers, he could not have stopped the introduction of English produce. It was against the nature of things, that the people who had been accustomed to cheap goods should buy dear ones; or that they should go without any article, whether of necessity or luxury, whose use had become general. Mark, therefore, if the cotton-spinners of Lancashire had triumphed sixty years ago over Arkwright's machinery, there would not have been a single man, woman, or child of those spinners employed *at all*, within twenty years after that most fatal triumph. The manufacture of cotton would have gone to other countries; cotton spinning in England would have been at an end. The same thing would have happened if the power-loom, twenty years ago, had been put down by combination; that is, if the hand-loom weavers

had not been as well-informed and as reasonable as we see they are. Mr. Fielden, whose evidence we have already quoted, says, "The introduction of the power-loom, I conceive, will be the cause of saving the manufactures to this kingdom; without the power-looms the manufactories must be annihilated entirely, for the Americans are making use of the power-loom."

Those who have taken a superficial view of the question of machinery say, that, whenever there is a greater demand than the existing means can supply, every new discovery in mechanics is a benefit to society, because it gives the means of satisfying the existing wants. They add, that, on the contrary, whenever the things produced are sufficient for the consumers, the discovery is a calamity, because it does not add to the enjoyments of the consumers; it only gives them a better market, which better market is bought at the price of the existence of the producers.

All such reasoning is false in principle, and unsupported by experience. There is no such thing, nor, if machines went on improving for five hundred years at the rate they have done for the last century, could there be any such thing, as a limit to the wants of the consumers. The great mass of facts which we have brought together in this book must have shown you, that the cheaper an article of necessity becomes, the more of it is used; that when the most pressing wants are supplied, and supplied amply by cheapness, the con-

sumer has money to lay out upon new wants; and when these new wants are supplied cheaply, he goes on again and again to other new wants; that there are no limits, in fact, to his wants as long as he has any capital to satisfy them. Bear in mind this; that the first great object of every invention and every improvement is to confer a benefit upon the consumers,—to make the commodity cheap and plentiful. The working man stands in a double character; he is both a producer and a consumer. But we will be bold to say that the question of cheapness of production is a much more important question to be decided in his favor as a consumer, than the question of dearness of production to be decided in his favor as a producer. The truth is, every man tries to get as much as he can for his own labor, and to pay as little as he can for the labor of others. If a mechanic, succeeding in stopping the machine used in his own trade, by any strange deviation from the natural course of things were to get higher wages for a time, he himself would be the most injured by the extension of the principle. When he found his loaf cost him two shillings instead of one; when he was obliged to go to the river with his bucket for his supply of water; when his coals cost a guinea a bushel instead of eighteen-pence; when he was told by the hosier that his worsted stockings were advanced from a shilling a pair to five shillings; when, in fact, the price of every article that he uses should be doubled, trebled, and,

in nine cases out of ten, put beyond the possibility of attainment;—what, we ask, would be the use to him of his advance in wages? Let us never forget that it is not for the employment of laborers, but for the benefit of consumers, that labor is employed at all. The steam-engines are not working in the coal-pits of Northumberland, and the ships sailing from the Tyne to the Thames, to give employment to colliers and to sailors, but to make coals cheap in London. If the people of London could have the coals without the steam-engines and the ships, it would be better for them, and better for the rest of the world. If they could get coals for nothing, they would have more produce to exchange for money to spend upon other things; and the comforts, therefore, of every one of us would be increased.

This increase of comfort, some of you may say, is a question that more affects the rich than it affects us. This again is a mistake. The whole tendency of the improvements of the last four hundred years has not only been to lift the meanest of you, in regard to a great many comforts, far above the condition of the rich four hundred years ago, but absolutely to place you, in many things, upon a level with the rich of your own day. You are surrounded, as we have constantly shown you throughout this book, with an infinite number of comforts and conveniences which had no existence two or three centuries ago; and those comforts and conveniences are not used only by a few,

but are within the reach of almost all men. Every day is adding something to your comfort. Your houses are better built,—your clothes are cheaper,—you have an infinite number of domestic utensils, whose use even was unknown to your ancestors,—you can travel cheaply from place to place, and not only travel at less expense, but travel ten times quicker than the richest man could travel two hundred years ago. Above all, you are not only advancing steadily to the same level in point of many comforts with the rich, but you are gaining that knowledge, which was formerly their exclusive possession. Keep fast hold of that last and best power; and you will learn what your true individual interest is, in every situation in which you can be placed: you will learn now, that it is useless in any way to struggle against that progress of society, whose tendencies are to make all of us more comfortable, more instructed, more virtuous, and, therefore, more happy.

We have endeavored to show, throughout this book, that the one great result of machinery, and of every improvement in art, is to lessen the cost of production; to increase the benefit to the consumer. But it is a most fortunate arrangement of the social state, as we have also shown you all along, that cheap production gives increased employment. The same class of false reasoners who consider that the wants of society are limited, cry out, it is better to have a population of men than of steam-engines. That might be true, if the

steam-engines *did* put out the men; but inasmuch as they increase the productions by which men are maintained, they increase the men. What has increased the population of England nearly ten-fold during the last five hundred years, but the improvement of the arts of life, which has enabled more men to live within the land? There is no truth so clear, that as the productions of industry multiply, the means of acquiring those productions multiply also. The productions which are created by one producer, furnish the means of purchasing the productions created by another producer; and, in consequence of this double production, the necessities of both the one and the other are better supplied. The multiplication of produce multiplies the consumers of produce. There are, probably, upon the average, no more hats made in the year than there are heads to wear them; but as there are fifteen millions of heads of the British subjects of King William IV., and there were only five millions of the British subjects of Queen Anne, it is self-evident that the hat-makers have three times as much work as they had a century and a quarter ago. What has given the hat-makers three times as much work? The trebling of the population. And what has trebled the population? The trebling of produce,—the trebling of the means of maintaining that population.

CHAPTER XIX.

If you have rightly considered the various facts which we have thus presented to you, you will long before this have come to the conclusion, that it is for the general interests of society that every invention, which has a tendency to diminish the cost of production, shall have the most perfect freedom to go forward. You will also have perceived, that the exercise of this natural right, this proud distinction, of man, to carry on the work of improvement to the fullest extent of his capacity and knowledge, can never be wholly stopped, however it may be opposed. It may be suspended by the ignorance of a government—it may be clamored down by the prejudice of a people; but the living principle which is in it can never be destroyed. To deny that this blessing, as well as many other blessings which we enjoy, is not productive of any particular evil, would be uncandid and unwise. Every change produced by the substitution of a perfect machine instead of an imperfect one, of a cheap machine instead of a dear one, is an inconvenience to those who have been associated with the imperfect and the dear machines. It is a change that more or less affects the interests of capitalists as well as of workmen. In a commercial country, in a highly civilized community, improvement is hourly producing some change which affects some interests Every

new pattern which is introduced in hardware deranges for a moment the interests of the proprietors of the old moulds. Every new book, upon any specific subject upon which books have formerly been written, lessens the value of the copyright of those existing books—What then? Is every improvement, which thus produces a slight partial injury, to be discountenanced, because of this inevitable condition which we find at every step in the march of society? Or rather, ought we not to feel that every improvement brings healing upon its wings, even to those for whom it is a momentary evil;—that if it displaces their labor or their capital for a season, it gives new springs to the general industry, and calls forth all labor and all capital to higher and more successful exertions?

At every advance which improvement makes, the partial and temporary evils of improvement are more and more lessened. In the early stages of social refinement, when a machine for greatly diminishing labor is for the first time introduced, its effects in displacing labor for an instant may be seen in the condition of great masses of people. It is the first step which is the most trying. Thus, when printing superseded the copiers of books by writing, a large body of people were put out of employ;—they had to seek new employ. It was the same with the introduction of the spinning machinery,—the same with the power-loom. It would be presumptuous to say that no such great changes could again

happen in any of the principal branches of human industry; but it may be said, that the difficulty of introducing more expeditious and cheaper modes of manufacture is daily increasing. The more machines are multiplied, that is, the more society approaches towards perfection, the less room is there for those great inventions which change the face of the world. We shall still go on improving, doubtless; but ingenuity will have a much narrower range to work in. It may perfect the machines which we have got, but it will invent fewer new machines. And who can doubt, that the nearer we approach to this state, the better will it be for the general condition of mankind? Who can doubt whether, instead of a state of society where the laborers were few and wretched, wasting human strength, unaided by art, in labors which could be better performed by wind, and water, and steam,—by the screw and the lever—it would not be better to approach as nearly as we can to a state of society where the laborers would be many and lightly tasked, exerting human power in its noblest occupation, that of giving a direction by its intelligence to the mere physical power which it had conquered? Surely, a nation so advanced as to apply the labor of its people to occupations where a certain degree of intelligence was required, leaving all that was purely mechanical to machines and to inferior animals, would produce for itself the greatest number of articles of necessity and convenience, of luxury and taste, at the

cheapest cost. But it would do more. It would have its population increasing with the increase of those productions; and that population employed in those labors alone which could not be carried on without that great power of man, by which he subdues all other power to his use,—his reason.

But while we are approaching towards this condition, the state of change, which always follows a state of improvement, has more or less in it of the positive suffering and the heart-wearing uncertainty which belong to all changes. It is not for us to point out what may be expected from the collective exertions of *society*, to mitigate or to remove the partial and temporary evils which follow in the train even of improvement. Of one thing we are certain. Society can never interfere to stop the improvement; and if any portion of society, who feel the individual suffering, but cannot see the general good, should interfere, with an unavailing violence, to attempt to check that which must go forward, then the laws of society must step in to protect us all, themselves amongst the number, from the consequences of lawless acts. Beyond this observation, we shall not attempt to discuss that part of the question which belongs to the duty of a government. Our business is with the people themselves—with the working people; and to them we would offer a few concluding observations upon the means which they possess, *in themselves*, to remedy the inconvenience of any state of change.

The first thing that we say to every working-man is, get knowledge. By knowledge, we do not mean the arts alone of reading and writing, which are only the keys to knowledge; but that sound practical acquaintance with the elements of science, both moral and physical, which may give working-men a right knowledge of the things by which they are surrounded, and enable them to form a right estimate of their own capabilities and their own duties. By knowledge, neither do we mean only that acquaintance with books which refines and elevates the mind; but an acquaintance with every thing about them, and especially with the mechanical arts which properly belong to, or are allied with, their own trade. The first employment which we ask them to make of this practical knowledge, is to acquire the readiness of shifting their occupation. It is not the increase of machinery, or the occasional glut of laborers, which alone compel the working-man to pass through a state of change. The caprices of fashion, which, upon the whole, create employment, also make that employment irregular. A change from metal buttons to silk buttons is alone sufficient to derange the industry of hundreds of workmen. What then is the remedy? Knowledge. The power of knowing what employments are in any degree allied to your own employments, and how your own employments may receive a new impulse from your own ingenuity. There are constant fluctuations, for instance, between

the demands for silk and the demands for cotton. The spinners and weavers have learnt to adapt themselves to these fluctuations. At Manchester, at the present moment, there are twenty thousand men working at silk, who, two years ago, were working at cotton. We have seen how the lace-makers of Marlow, instead of struggling against the lace-machine, applied themselves to embroider caps. In both these cases, these salutary changes of employment could not have been effected without a certain degree of knowledge. But the great advantage of such practical knowledge to you all, is that you may strike out new sources of industry. Whenever you can do a thing better,—that is, when you can improve the quality of an article and add to its cheapness,—you may be sure of creating a demand for it. We have shown you that there is no limit to the wants of society; and that whatever increases the quantity of productions also increases the number of consumers. It is the duty of females, especially, to apply that ingenuity which peculiarly belongs to them, to the produce of articles which may add to the stock of human comfort. Some of their old domestic labors are almost entirely displaced by machinery. There are infinitely more females, certainly, employed in conjunction with machinery; and as there are more clothes worn, there is more employ for the female makers of clothes. But still, females are greatly affected by changes of fashion; and the only way to meet these changes is to be in the constant

habit of exercising their taste and their ingenuity, to create new changes, and, therefore, new employment.

But, you will say, "While the grass grows the steed starves." Certainly, if there be no provision of former grass. A change is necessary for your employment. There is a less demand for the article you are engaged in producing. There is a glut of laborers in the market. If you continue in the market of labor during this glut, your wages must fall. What is the remedy? To go out of the market. When wheat falls five shillings a quarter at Mark Lane, the farmer receives a hint that the supply is beyond the demand; he holds back for a few weeks, and prices regain their former level. What enables the farmer to hold back his corn? He has something to fall back upon; he is not compelled to sell his corn that week or that month; he is a capitalist. Endeavor to acquire the same power yourselves. Become capitalists. When there is too much labor in the market, and wages are too low, do not combine to raise the wages; do not combine with the vain hope of compelling the employer to pay more for labor than there are funds for the maintenance of labor: but go out of the market. Leave the relations between wages and labor to equalize themselves. You can never be permanently kept down in wages by the profits of capital; for if the profits of capital are too high, the competition of other capital immediately comes in to set the matter right. But you

may be kept down, and you are kept down, by yourselves. When wages fall by a glut of labor, you not only continue to work, but you work harder; and thus you increase the evil. You have, in too many cases, nothing but your labor for your support. We say to you, get something else; acquire something to fall back upon. When there is a glut of labor, go at once out of the market; become yourselves capitalists. How is this to be done? We will tell you.

In England, Wales, and Ireland, there are about four hundred and eighty banks for savings. The sum of money deposited in these banks is fourteen millions five hundred thousand pounds. The number of depositors is four hundred and ten thousand. The average amount of the sum deposited by each person is thirty-five pounds. The greater number of persons who are depositors in savings' banks are working-men and women. They are the capitalists, who, together, have accumulated a capital of above fourteen millions of money, and receive an annual interest upon that capital of about half a million. How has this great sum of money been accumulated? By small savings. The man who, at the age of twenty-one, puts only one shilling a-week in a savings'-bank, and continues to do so till he is thirty years of age, has acquired a capital of above thirty pounds. If he has saved, during the same time, two shillings a-week, he has a capital of above sixty pounds. If three shillings a-week, he has acquired a hun-

dred pounds.* How many working-men are there who are compelled to glut and overstock the market for labor, because they have not the means to go out of that market even for a few weeks! And yet we see that if a single man steadily lays by three shillings a-week for nine years, at the end of that time he has capital enough to live upon, without working at all, for at least three years. But he will not live long upon his capital. The same habits which made him frugal, have also made him honest, sober, and industrious. He may suffer for a season by some change in the trade to which he has applied himself; but his capital enables him to look about him, without undergoing any serious privations. He strikes into some new line of labor; or he resolves to see what his capital and labor will do together as a workman on his own account; or he waits patiently till the change has passed over, and then takes back his labor to a market which, demanding it, is ready abundantly to pay for it. Who, on the contrary, is always the first and the last to suffer by every change in the demand for labor? The unskilful workman, the drunken workman, the unthrifty workman, the workman, in fact, who only got employ at all when there was more labor to be done than there were good workmen to do it; the workman who did not avail himself of that golden opportunity to acquire skill, and to learn prudence; the workman, who, in nine

* See Appendix, No. VIII. p. 216.

cases out of ten, has compelled capitalists to set up machines, that they, as well as the steady industrious men whom they cherish, may be independent of the unsteady and the idle men;—the workman, in a word, who would die in a ditch, whether he lived in a country with machines or without machines, because he is without the power of intellectual exertion, and possesses not the best thing which that power gives, moral conduct.

It is a prayer in which all good men unite, that the condition of the working-classes may be improved,—that their outward circumstances may be made better. But those who labor the steadiest, and the most zealously, in the endeavor to realize this hope, feel, that the day of this amelioration is far removed by the clamors of anarchy and misrule. They know that every improvement in the arts of life improves also the condition of the humblest working-man in the land; and they also know that every successive improvement has a tendency to lessen the inequality in the distribution of wealth. But, if the condition of the working-men of these kingdoms is to be permanently improved,—if they are to obtain a full share of the blessings which science and industry confer upon mankind,—they must win those blessings by their own moral elevation. They cannot snatch them by outrage and violence; they must win them by peaceful and steady exertion. This great triumph, to use the language of a wise and most benevolent minister of religion, Dr. Chalmers,

"will not be the achievement of desperadoes. It will be come at through a more peaceful medium—through the medium of a growing worth and growing intelligence among the people. It will bless and beautify that coming period, when a generation, humanized by letters, and elevated by the light of Christianity, shall, in virtue of a higher taste, and a larger capacity than they now possess, cease to grovel among the sensualities of a reckless dissipation." When the working-men of this country shall feel, as many of them already feel, that knowledge is power, they will next set about to see how that power shall be exercised. The first tyranny which that power must hold in check is the tyranny of their own evil habits—those habits, which, looking only to the present hour, at one time plunge them into all the thoughtless extravagance which belongs to a state of high wages—at another, throw them prostrate before their employers, in all the misery and degradation which accompany a state of low wages, without a provision for that state. It is for them, and for them alone, to equalize the two conditions. The changes of trade, in a highly commercial country like this, must be incessant. It is for the workmen themselves to put a "*governor*" on the commercial machine, as far as they are concerned; in a season of prosperity, to accumulate the power of capital—in a season of adversity, to use effectively, because temperately, that power which they have won for themselves.

And do not let it be imagined, that when we advocate frugality, we would cut off from the working-man one single real comfort or enjoyment which he now possesses. We would rather say, add in every way that you possibly can to the stock of your real comforts and enjoyments. Do not be satisfied with a mud hovel, when you can get a snug cottage. Do not be satisfied with a ragged coat when you can get a decent one. Do not be satisfied with dirt when you can get cleanliness. Do not be satisfied with ignorance when you can get knowledge. Extend, as much as you can, the range of your lawful desires, and your lawful enjoyments. Cultivate your understandings, elevate your tastes. You will find, when you come rightly to know their value, that those things which afford you the purest and most enduring pleasures, are infinitely less costly than those gratifications which are sensual and transitory. We would raise your standard of enjoyment. We would make it impossible that you should feel any enjoyment in what is grovelling and vicious.

We ask you to reduce these general maxims to the test of your own experience. You must have observed amongst your own acquaintances, you must have seen amongst the workmen of your own trade, some one man who always had a good coat on his back; who had a decent house; supported well-fed and well-clothed children; and, as far as you could judge, possessed not only all the ordinary comforts of his station, but many little luxuries and

conveniences, which, somehow or other, he was able to acquire, and not ready to lose. This man had no higher wages than his fellow-workmen; and he did not work more hours than it was the custom of the trade to work. But you never saw him lose any time;—you never saw him at the gin-shop or the ale-house;—his comforts were in his home, and he was determined that his home *should* be comfortable. If there was a slackness of work in your trade, that man was the last to be discharged by his employers. In fact, every expedient was used to find him employ. There was a natural connexion between that man and his employers, which it seemed impossible to sever. Was that man servile to his employers? Was he not rather the most independent of you all? If an act of oppression was ever meditated against him, was he not the first to say, I shall not submit to it? And did not his quiet resistance always conquer in the end?

We ask you, now, to direct your attention another way. Your own experience must have often shown you too many men whose condition was the entire opposite of that of the man we have described. You must have seen some one man who never had a good coat on his back; whose house was ruinous and filthy; whose children were dirty and in rags; who, as far as you could judge, had very few of the common comforts of his station, and who had no luxuries and conveniences at all. This man had no lower wages

than his fellow-workmen; he did not work fewer hours than was the custom of his trade; but, somehow, he never got on. He seemed to feel that he could not get on. He spent his evenings always at the ale-house; he had no comforts at home, and he did not appear to wish that his home should be made comfortable. When there came a slackness of work in the trade, this man was the first to be sent off. There appeared to be no strong natural bond between him and his employers; it was snapt in a minute when the day of adversity came. Was not this man the most timid and slavish of you all? Was he not the first to break forth in complaints when there was plenty of work and few to do it; and the first to submit to any act of oppression when there was little work and a great many striving to do it?

What constituted the great difference in the character of these two men? The difference was this. The standard of enjoyment in the one man was high; the standard of enjoyment in the other was low. The one man was determined, early in life, not to be satisfied with poverty if he could get wealth—not to be satisfied with discomforts, if he could get comforts. But he knew that it was as necessary for him to make himself *secure*, as far as human beings can obtain security, that what he acquired should not be taken away from him. The power by which he accomplished this—the barrier which he set up against ill-fortune—was frugality. He first learnt to prefer real comforts to low dissipation; and, by avoiding

the expense of that low dissipation, he not only got more real comforts, but he elevated his mind to desire, whilst he saved the means of procuring, those luxuries and conveniences which were somewhat above the ordinary possessions of his station. In one word, he was an intelligent man, and he was a prudent man. He saw what was good, and he applied himself to obtain it, and to preserve it when it was obtained. He saw, for instance, that it was good to marry; but he also saw, that if he married before he had saved something against an evil day, he should not only put his own happiness in peril, but he should endanger the happiness of other beings. He would not marry to lower his standard of enjoyment; he did not marry, till he had taken care that the wants of a family did not lower him in the scale of respectability. It is not necessary for us to follow up the comparison between the one man and the other, to whom we directed your attention. He acted upon entirely different principles; and his condition through life was entirely different.

What is the lesson which we ask you, the working men of this country, to draw from the exhibition of these familiar examples? We ask you, *as a body*, to strive with all your power to raise the standard of your enjoyment. You have within your reach, through the progress of invention, an infinitely greater share of the comforts and conveniences of life than your forefathers enjoyed. When you set out in the world, determine to have your full share of

these comforts and accommodations. You cannot make the determination without perceiving how the end is to be obtained. Knowledge, industry, and prudence, are the tools by which you must work out this good. "This," says the reverend author whom we have just quoted, "is one of those felicitous cases, in which the desire of good things is at length followed up by the power of obtaining them. It is thus that workmen can enforce their demand for higher wages. Those distempered outbreakings which approach to the character of rebellion will retard instead of forwarding their cause. But nothing can arrest the march of light among the people; and when this light is conjoined with virtue, it will guide their ascending way to a vantage-ground, where they will make good the precise condition to which their worth shall entitle them."

London, Dec. 28, 1830.

APPENDIX.

_ As references are constantly made in the preceding work to Parliamentary Returns, and other Tables, we select a few of the more important.

I.—Population.

The United Kingdom contains, according to the returns for Great Britain made in 1821, and the best returns for Ireland, 117 county towns, and 13,885 parishes, and possesses a population of 21,238,580 souls, constituting 4,253,416 families employed as follows:

In agriculture	1,198,186 families.
Trade, manufactures, &c. .	1,677,886
Not comprised in either of the preceding classes	1,377,344
Total	4,253,416

II.—Population throughout the last Century.

England and Wales.

In what year.	Population.	In what year.	Population.
1700	...5,475,000	1760	...6,736,000
1710	...5,240,000	1770	...7,428,000
1720	...5,565,000	1780	...7,953,000
1730	...5,796,000	1790	...8,675,000
1740	...6,064,000	1801	...9,168,000
1750	...6,467,000		

III.—Land in the United Kingdom.

In the third report of the Emigration Committee, the following Table for Great Britain is given:—

General Statement of Cultivated, Uncultivated, and Unprofitable Land of the United Kingdom.

	Cultivated.	Uncultivated Wastes capable of Improvement.	Unprofitable.	Total.
	ACRES.	ACRES.	ACRES.	ACRES.
England.....	25,632,000	3,454,000	3,256,400	32,342,400
Wales.......	3,117,000	530,000	4,105,000	4,752,000
Scotland.....	5,265,000	5,950,000	8,523,930	19,738,930
Ireland......	12,125,280	4,900,000	2,416,664	19,441,944
British Islds..	383,690	166,000	569,469	1,119,159
	46,522,970	15,000,000	15,871,463	77,394,433

Of the cultivated land in Great Britain, it has been estimated that 14 millions of acres are arable, and 20 millions meadow and pasture.

IV.—Comparative Estimate of the Amount of Animate and Inanimate Force applied to Agriculture and the Arts, in France and Great Britain.

(Abridged from M. Charles Dupin, and published in the Companion to the Almanac for 1829.)

The 31,800,000 inhabitants, which now constitute the population of France, are equivalent to a power of 12,609,057 individuals of the male sex, at the age of full vigor. It is a position generally admitted in France, that two-thirds of the population are employed in agriculture; and that a third only is occupied in manufacturing and commercial pursuits. Hence it results that France possesses

	Laboring Men.
A human agricultural power equivalent to that of	8,406,038
And a power of industry, manufacturing and commercial, equal to	4,203,019
Total	12,609,057

Were it not that the industry of man had found

the means of calling extraneous force to its aid, its means would be confined to the amount of power above enumerated: but man employs other forces than his own in agricultural labors, and principally that of the horse, of the ass, of the mule, the ox, and the cow; and with the help of these, the animate agricultural force of France has increased to the following sum:—

			Effective Laborers.
Human race . .	21,056,667	equivalent to	8,406,038
Horses . . .	1,600,000		11,200,000
Oxen and cows .	6,973,000		17,432,000
Asses	240,000		240,000
		Total	37,278,038

On making similar calculations of the agricultural force of Great Britain, and stating at 15,000,000 the number of inhabitants of England and Scotland, of whom a third only are employed in agriculture, and the other two-thirds in commerce and manufactures, we shall have,

	Effective Working Men.
Agricultural force	2,132,446
Artisans of all professions . . .	4,264,893
Total	6,397,339

If we proceed in the same way with regard to Great Britain, as we have done with respect to France, and make a comparative calculation of the power in men, and the power in other animals, engaged in agriculture, we shall find,

			Effective Laborers.
Human race . . .	5,000,000	equivalent to	2,132,446
Horses of full growth	1,250,000		8,750,000
Oxen, cows, &c. .	5,500,000		13,750,000
		Total	24,632,446
		Ireland; approximating estimate	7,455,701
		Total for the United Kingdom	32,088,147

Taking the proportion of this total force of 24,632,446, to the human force applicable to agriculture, we find it to be as 12. Whence it appears that the agriculturists of England and Scotland have discovered the means of creating a force, twelve times the amount of their personal corporeal force, by the use they make of domestic animals; while the additional force obtained through similar means by the French agriculturists, does not amount to five times their own. It is calculated that in France there are 46,000,000 hectares of land made to yield produce; so that there is an animate power equal to that of 810 laborers, for the cultivation of every thousand hectares. The total number of hectares of productive land in Great Britain is 21,643,000; so that there is an animate power equal to that of 1138 working men for every thousand hectares. The produce of the land, in the respective countries, is in proportion to the power employed respectively in its cultivation. The case is the same in regard to manufactures.

The human force in France employed in commercial and manufacturing industry is equivalent, according to the calculations already stated, to 4,203,019 effective working men; to this power must be added that supplied by the use of horses, the number of which is computed at 300,000 employed in transport, for the saddle, in draught, &c. whereby the animate force of France is raised to 6,303,019 power of men.

The human force of Great Britain employed in commerce and manufactures, is equivalent to 4,264,893 effective men; to this power there must also be added the power of 250,000 animals, employed in divers works of industry. These will raise the animate force of England and Scotland to 6,014,893: to which there must be superadded the approximating value of 1,260,604 effective men for

Ireland: so that the commercial and manufacturing animate power of the United Kingdom must be computed at 7,275,497 laboring men.

To these animate powers should be joined also, in the case of both the countries, the inanimate powers, or the force supplied by water, wind, and steam: and the whole productive and commercial manufacturing power of England and France will be ascertained.

The total number of mills in France has been computed by the French authors on statistics at 76,000, of which about 10,000 may be set down as windmills; the total force of hydraulic machines employed for forges, furnaces, and machinery of every kind, is equal to the third part of that of the 10,000 windmills; the wind as employed in navigation is equivalent to the power of 3,000,000 of men; and, lastly, the steam-engines in operation in France exceed the power of 60,000 dynames, equivalent to the power of 480,000 working men turning a winch.

It has been calculated also, by the same writers, that besides windmills, hydraulic machines, &c., Great Britain possesses in steam-engines alone a moving power of at least 800,000 dynames, the effect of which is equal to the power of 6,400,000 men employed at the windlass. The commercial and manufacturing power of France is, therefore, in proportion to that of Great Britain, as follows:—

		France. Men power.	Great Britain. Men power.
	Animate force . . .	6,303,019	7,275,497
Inanimate powers.	Mills & Hydrau. engines	1,500,000	1,200,000
	Windmills	253,333	240,000
	Wind and navigation .	3,000,000	12,000,000
	Steam-engines . . .	480,000	6,400,000
	Total force	11,536,352	27,115,497
		Ireland	1,002,667
		Total	28,118,164

Thus, the total of the inanimate force applied to the arts of all descriptions in France, scarcely exceeds the fourth of the same power applied to the same purposes in Great Britain; and the whole animate and inanimate power of Great Britain, applied to manufactures and commerce, is nearly treble the amount of that so applied in France. The agricultural power and the manufacturing and commercial power of the two countries bear a corresponding proportion to the total of the agricultural and manufactured produce, and their value in commerce.

NOTE.—A *hectare* contains 10,000 square metres, or 100 *ares*. An English *acre* is very nearly equal to 40 *ares;* therefore a *hectare* is about 2½ *acres*.

A *dyname* is equal to a thousand killograms raised to the height of 1000 metres; eight men employed at a winch can in one day raise a thousand killograms to the height of a thousand metres, or in other words, can produce a dyname of labor.

V.—Quantities and Declared Value of British and Irish Produce and Manufactures exported in 1828.

		Quantity.	Declared value. £
Apparel, slops, and haberdashery		——	910,090
Arms and ammunition		——	335,761
Bacon and hams . .	cwts.	8,333	28,809
Beef and pork . . .	barrels	33,451	113,906
Beer and ale . . .	tuns	11,374	245,496
Books, printed . . .	cwts.	4,336	102,874
Brass and copper manufactures	cwts.	128,106	678,786
Butter and cheese . .	cwts.	94,623	352,615
Coals, culm, and cinders	tons	357,864	145,943
Cordage	cwts.	52,420	119,652
Cotton Manufactures,—entered by the yard	yds.	363,328,431	12,483,249
Cotton hosiery, lace, and small wares . . .		——	1,165,763
Cotton twist and yarn	lbs.	50,505,751	3,595,405
Earthenware of all sorts	pieces	38,136,479	502,215
Fish—herrings . . .	barrels	134,137	157,532

		Quantity.	Declared value. £
Glass, entered by weight	cwts.	216,895	491,211
——, entered at value . . .		——	9,145
Hardware and cutlery	cwts.	242,272	1,387,204
Hats, beaver and felt	dozens	83,114	197,581
Iron and steel, wrought and unwrought .	tons	100,403	1,226,617
Lead and shot . . .	tons	10,021	177,983
Leather manufactures .	lbs.	1,321,542	273,976
Saddlery and harness . . .		——	89,600
Linen manufactures .	yds.	60,287,814	2,120,276
Linen threads, tapes, &c. . .		——	66,146
Machinery and mill-work .		——	262,115
Painters' colors		——	138,669
Plate, plated ware, jewellery, and watches		——	181,973
Salt	bushels	8,993,124	154,245
Silk manufactures		——	255,871
Soap and candles . .	lbs.	10,902,713	269,109
Stationary of all sorts . . .		——	208,532
Sugar	cwts.	456,844	1,038,569
Tin, unwrought . . .	do.	41,427	147,131
Tin and pewter wares . . .		——	266,651
Wool	lbs.	1,669,389	76,881
Woollen manufactures	pieces	1,820,631	4,397,291
Ditto	yds.	6,816,407	527,476
Woollen hosiery and small wares		——	201,216
All other articles		——	1,709,192
		Total . .	£36,812,756

VI.—Travelling in England a Century ago.

In December, 1703, Charles III., King of Spain, slept at Petworth on his way from Portsmouth to Windsor, and Prince George of Denmark went to meet him there by desire of the Queen. The distance from Windsor to Petworth is about forty miles. In the relation of the journey given by one of the Prince's attendants, he states—"We set out at six in the morning, by torchlight, to go to Petworth, and

did not get out of the coaches (save only when we were overturned or stuck fast in the mire) till we arrived at our journey's end. 'Twas a hard service for the Prince to sit fourteen hours in the coach that day without eating any thing, and passing through the worst ways I ever saw in my life. We were thrown but once, indeed, in going, but our coach, which was the leading one, and his Highness's body coach, would have suffered very much, if the nimble boors of Sussex had not frequently poised it, or supported it with their shoulders, from Godalming almost to Petworth, and the nearer we approached the Duke's house the more inaccessible it seemed to be. The last nine miles of the way cost us six hours' time to conquer them; and indeed we had never done it, if our good master had not several times lent us a pair of horses out of his own coach, whereby we were enabled to trace out the way for him." Afterwards, writing of his departure on the following day from Petworth to Guildford, and thence to Windsor, he says—"I saw him (the Prince) no more, till I found him at supper at Windsor; for there we were overturned (as we had been once before the same morning), and broke our coach; my Lord Delawarre had the same fate, and so had several others." —*Annals of Queen Anne, Vol. ii. Appendix, No.* 3.

VII.—Increase of Accommodations.

"Neither do I speak this reproach of any man, as God is my judge, but rather I do rejoice to see how God has blest us with his good gifts, and to behold how that, in a time where all things are grown to such excessive prices, we do yet find the means to obtain and achieve such furniture as heretofore has been found impossible. There are old men yet dwelling in the village where I remain, who have noted three things to be marvellously altered in England within their sound remembrance.

One is the multitude of chimnies lately erected, whereas in their young days there were but two or three, if so many, in most uplandish towns of the realm, the religious houses and manor houses of their lords always excepted, and peradventure some great personage. But each made his fire against a rere dosse in the hall where he dined, and dressed his meat. The second is the great amendment in lodging: for, said they, our fathers and ourselves have lain full oft on straw pallets, covered only with a sheet, under coverlets of dog's waine and hop harlots (I use their own terms), and a good round log under their head as a bolster. If it were so that the father or good man of the house had a mattress or flock bed, and thereon a sack of chaff to rest his head upon, he thought himself as well lodged as the lord of the town. Pillows, said they, are thought fit only for sick women; as for servants, if they had any sheet above them it was well, for seldom had they any under their bodies to keep them from the pricking straws that ran oft through the canvas and rased their hardened hides. The third thing they tell of is the exchange of trene platters (so called from tree, wood) into pewter, and wooden spoons into silver or tin; for so common were all sorts of trene vessels in those times, that a man could hardly find four pieces of pewter (of which one was peradventure a salt) in a good farm-house."—*Hollingshed's Chron.*

VIII.—Savings' Bank.

In England, Wales, and Ireland, there were, on the 20th of November, 1829, 487 Savings' Banks: from Nineteen Returns have not been made; the remaining contain

Number of Depositors.		Amount. £	s.	d.	Average Amount of each Depositor. £	s.	d.
203,691	under £20 each	1,471,796	7	4¼	7	4	5½
114,163	— 50 —	3,499,288	8	0	30	13	0
55,231	— 100 —	3,890,757	17	1¼	70	12	6¼
18,113	— 150 —	2,177,038	17	5¼	120	3	10
7,535	— 200 —	1,273,624	0	11	169	0	6½
4,979	above 200 —	1,210,923	8	5¾	245	4	3½
403,712	Depositors	13,523,428	19	3½	33	9	11½
4,549	Friendly Societies	747,124	11	5¼	164	4	9½
1,684	Charitable Societies	164,367	14	0¾	97	12	1¼
Total 409,945	Accounts	14,434,921	4	9½	35	4	2¾

THE END.

KNOWLEDGE FOR THE PEOPLE:

OR THE

PLAIN WHY AND BECAUSE.

PART VII.—MECHANICS.

MECHANICS.

INTRODUCTORY.

Why are certain truths termed physical?

Because they explain the greater part of the phenomena of nature, the term physical being derived from the Greek word signifying *nature;* an appellation distinguishing them from *chemical* truths, which regard particular substances, and from *vital* truths, which have relation only to living bodies.—*Arnott.*

Why is an atom so called?

Because of its origin from a Greek word signifying *that which cannot be farther divided;* or, an exceedingly minute resisting particle.

Why is the term attraction used?

Because the atoms of which the visible universe is built up, whether separate, or already joined into masses, tend towards all other masses, with force proportioned to their proximity: as, when any body presses or falls towards the great mass of the earth, or when the tides on the earth rise towards the moon.

Why is the term repulsion used?

Because, under certain known circumstances, as of heat diffused among the particles, their mutual *attraction* is countervailed or resisted, and they tend to separate with force proportioned to their proximity: as, when heated water bursts into steam, or when gunpowder explodes.

Why is the term inertia used?

Because it denotes that the atoms, in regard to motion, have about them what may be figuratively called a *stubbornness*, tending always to keep them in their existing state, whatever it may be; in other words, that bodies neither acquire motion, nor lose motion, nor bend their course in motion, but in exact accordance to some force applied.

This, and the three preceding definitions, are derived from the Synopsis of Dr. Arnott's valuable *Elements of Physics*, Part I. third edit. 1828; the author pertinently observing, that "a person comprehending fully the import of these four words, *atom*, *attraction*, *repulsion*, *inertia*, may predict or anticipate correctly, very many of the facts and phenomena which the extended experience of a life can display to him."

Why are not men sensible of the rapid motion of the earth?

Because all things move at the same rate. Whatever *common* motions objects may have, it does not interfere with the effect of a force producing any new relative motion among them. All the motions seen on earth are really only slight differences among the common motions: as, in a fleet of sailing ships, the apparent changes of place among them are, in truth, only slight alterations of speed or direction in their individual courses.

Why does a spire or obelisk stand more securely on the earth, than a pillar stands on the bottom of a moving wagon?

Because the motion of the earth is uniform, and not that the earth is more at rest than the wagon. Were the present rotation of our globe to be arrested but for a moment, imperial London, with its thousand spires and turrets, would be swept from its valley towards the eastern ocean, just as loose snow is swept away by a gust of wind.—*Arnott.*

Why does a ball, let drop from the hand, fall with greater velocity the nearer it approaches the earth?

Because, owing to the inertia of matter, any force continuing to act on a mass which is free to obey it, produces in the mass a quickening or accelerated motion; for, as the motion given in the first instant, continues afterwards without any farther force, merely on account of the inertia, it follows that as much more motion is added during the second instant, and as much again during the third, and so on. A falling body, therefore, under the influence of attraction, is, as it were, a reservoir, receiving every instant fresh velocity and momentum (or quantity of motion). The height of a precipice, or the depth of a well, may be judged of with considerable accuracy, by marking the time required for a body to fall through the space. A body falls four times as far in two seconds as in one, although the velocity, at the end of two seconds, is only doubled.—*Arnott.*

A body falls by gravity precisely 16 1-16 feet in a second, and the velocity increases according to the squares of the time: *viz.*

In ¼″ (quarter of a second) a body falls		1	foot.
½″ (half a second)	ditto	4	
1 second	ditto	16	
2 ditto	ditto	64	
3 ditto	ditto	144	

The power of gravity at two miles distance from the earth, is four times less than at one mile; at three miles, nine times less; and so on. It goes on lessening, but is never destroyed.

Meteoric stones, falling from great heights, bury themselves deep in the earth, by the force of their gradually acquired velocity.

Why are we said to know of nothing which is absolutely at rest?

Because the earth is whirling round its axis, and

round the sun; the sun is moving round his axis, and round the centre of gravity of the solar system; and, doubtless, round some more remote centre in the great universe, carrying all his planets and comets about his path.

One of the grand laws of nature is, that all bodies persevere in their present state, whether of motion or rest, unless disturbed by some foreign power. Motion, therefore, once begun, would be continued for ever, were it to meet with no interruption from external causes, such as the power of gravity, the resistance of the medium, &c.

Dr. Arnott adduces several familiar illustrations of motions and forces. Thus, all falling and pressing bodies exhibit *attraction* in its simplest form. *Repulsion* is instanced in explosion, steam, the action of springs, &c. Explosion of gunpowder is repulsion among the particles when assuming the form of air. Steam, by the repulsion among its particles, moves the piston of the steam-engine. All elasticity, as seen in springs, collision, &c. belongs chiefly to repulsion. A spring is often, as it were, a reservoir of force, kept ready charged for a purpose; as when a gun-lock is cocked, a watch wound up, &c.

Why does a billiard ball stop when it strikes directly another ball of equal size, and the second ball proceed with the whole velocity which the first had?

Because the action which imparts the new motion is equal to the reaction which destroys the old. Although the transference of motion, in such a case, seems to be instantaneous, the change is really progressive, and is as follows: The approaching ball, at a certain point of time, has just given half of its motion to the other equal ball; and if both were of soft clay, they would then proceed together with half the original velocity; but, as they are elastic, the touching parts at the moment supposed, are compressed like a spring between the balls; and by their expanding,

and exerting force equally both ways, they double the velocity of the foremost ball, and destroy altogether the motion in the other.

Why is the uniformity of motion essential to rational conjecture or anticipation as to future events?

Because, it is by assuming, for instance, that the earth will continue to turn uniformly on its axis, that we speak of *to-morrow* and of *next week*, &c. and that we make all arrangements for future emergencies: and were the coming day or season, or year, to arrive sooner or later than such anticipation, it would throw such confusion into all our affairs that the world would soon be desolate.

To calculate futurities, then, (observes Dr. Arnott) or, to speak of past events, is merely to take some great uniform motion as a standard with which to compare all others; and then to say of the remote event, that it coincided, or will coincide, with some described state of the standard motion. The most obvious and best standards are the whirling of the earth about its axis, and its great revolution round the sun. The first is rendered very sensible to man by his alternately seeing and not seeing the sun, and it is called *a day;* the second is marked by the succession of the seasons, and it is called *a year.* The earth turns upon its axis about 365 times while it is performing one circuit round the sun, and thus it divides the year into so many smaller parts; and the day is divided into smaller parts, by the progress of the earth's whirling being so distinctly marked, in the constantly-varying directions of the sun, as viewed from any given spot on the face of the earth. When advancing civilisation made it of importance to man to be able to ascertain with precision the very instant of the earth's revolution, connected with any event, various contrivances were introduced for the purpose. Such have been sun-dials, where the shadow travels pro-

gressively round the divided circle; the uniform flux of water through a prepared opening; the flux of sand in a common hour-glass, &c. But the very triumphs of modern ingenuity and art are those astronomical clocks and watches, in which the counted equal vibrations of a pendulum, or balance-wheel, have detected periodical inequalities even in the motion of the earth itself, and have directed attention to unsuspected disturbing causes, important to be known.

Why, when a body is carried below the surface of the earth, does its weight become less?

Because the matter then above it is drawing it up, instead of down, as before. A descent of a few hundred feet makes a sensible difference, and at the centre of the earth, if man could reach it, he would find things to have no weight at all; and there would be neither up nor down, because bodies would be equally attracted in all directions.—*Arnott.*

Why is a horseman standing on the saddle enabled to leap over a garter extended over the horse, (the horse passing under the garter,) and to light upon the saddle at the opposite side?

Because, the exertion of the performer, in this case, is not that which he would use were he to leap from the ground over a garter at the same height. In the latter case, he would make an exertion to rise, and at the same time, to project his body forward. In the case, however, of the horseman, he merely makes that exertion which is necessary to rise directly upwards to a sufficient height to clear the garter. The motion which he has in common with the horse, compounded with the elevation acquired by his muscular power, accomplishes the leap.

Why does a walking stick help a man on a journey?

Because he pushes against the ground with the stick, which may be considered as compressing a spring

between the earth and the end of his stick, which spring is therefore pushing up as much as he pushes down; and if, at the time, he were balanced in the scales of a weighing beam, he would find that he weighed just as much less as he were pressing with his stick.

Why does a person wishing to leap over a ditch or chasm, make a run first?

Because the motion thereby acquired may help him over. A standing leap falls much short of a running one.

These facts also illustrate the same principle:—From a glass of water suddenly pushed forward on a table, the water is spilt or left behind, but if the glass be already in motion, as when carried by a person walking, and if it be then suddenly stopped by coming against an impediment, the water is thrown or spilt forward. Again, the actions of beating a coat or carpet with a cane to expel the dust; of shaking the snow from one's shoes by kicking against the door-post; of knocking a dusty book against a table, or shutting it violently.

Why is a man jumping from a carriage at speed, in great danger of falling, after his feet reach the ground?

Because his body has as much forward velocity, as if he had been running with the speed of the carriage; and unless he advance his feet as in running, he must as certainly be dashed to the ground, as a runner whose feet are suddenly arrested.—*Arnott.*

Why will the recoil of a fowling-piece hurt the shoulder, if the piece be not held close to it?

Because the piece recoils with as much motion or momentum in it as the ball has; but the momentum in the gun being diffused through a greater mass, the velocity is small, and easily checked.

Why does a sky-rocket ascend?

Because, after it is lighted, the lower part is always

producing a large quantity of aëriform fluid, which, in expanding, presses not only on the air below, but also on the rocket above, and thus lifts it. The ascent is aided also by the recoil of the rocket from the part of its substance, which is constantly being shot downwards.—*Arnott.*

Why does a hare, though much less fleet than a greyhound, often escape it?

Because the greyhound is, with the hare, a comparatively heavy body, moving at the same or greater speed in pursuit. The hare *doubles*, that is, suddenly changes the direction of her course, and turns back at an oblique angle with the direction in which she had been running. The greyhound, unable to resist the tendency of its body to persevere in the rapid motion it had acquired, is urged forward many yards before it is able to check its speed and return to the pursuit. Meanwhile the hare is gaining ground in the other direction, so that the animals are at a very considerable distance asunder when the pursuit is recommenced.

Why are a large and small ship sometimes seen sailing with the same velocity?

Because the surface of canvass or sail which they spread to catch the force of the wind, is proportioned to the difference of resistance which the water offers to the two.

Why are ships so often destroyed by running foul of each other at sea?

Because when two bodies moving in opposite directions meet, each body sustains as great a shock as if, being at rest, it had been struck by the other body with the united forces of the two. Thus, if two ships of 500 tons burden encounter each other, sailing at ten knots an hour, each sustains the shock, which, being at rest, it would receive from a vessel of 1000 tons burden, sailing ten knots an hour.

Why are carriages often overturned in quickly rounding corners?

Because the inertia carries the body of the vehicle in the former direction, while the wheels are suddenly pulled round by the horses into a new one. A loaded stage-coach running south, and suddenly turned to the east or west, strews its passengers on the south side of the road. Where a sharp turning in a carriage road is unavoidable, the outside of the bend should always be made higher than the inside, to prevent such accidents.

Why were the battering rams of the ancients such formidable engines of war?

Because they allowed the concentrated efforts of many hands, and a considerable duration of action, so as to give at last one great and sudden shock.

The action of gunpowder on bullets, although appearing so sudden, is still not an instantaneous, but a gradual, and therefore accelerating motion; and accordingly we find the effect to depend much on the length of the piece along which the force pursues the ball.—*Arnott.*

Why will a cannon or musket ball, shot quite horizontally, touch the ground of a level plane just as soon as another ball dropped at the same instant directly from the cannon's mouth?

Because the forward or projectile motion does not at all interfere with the action of gravity. This fact, observes Dr. Arnott, which most persons, before consideration, would be disposed to doubt, makes strikingly sensible the extraordinary speed of a cannon ball; *viz.* which has already carried it 600 or 800 feet before touching, during the half second that a ball dropped from the hand of a standing person requires to reach the earth. This fact also explains why, for a long range, the gun must always be pointed more or less upwards.—*Elements of Physics.*

The velocity of a musket ball is, on an average, 1,600 feet per second, and its range half a mile.

Why is this range only half a mile, whereas, by theory, it ought to be ten miles?

Because it is retarded by the resistance of the air.

In velocities exceeding 1,600 feet per second, the resistance of the air is greatly increased; hence the absurdity of giving balls too great an initial velocity. To give a bullet the velocity of 2000 feet per second, requires half as much more powder as to give it the velocity of 1,600 feet; yet after both have moved 400 feet, the difference between the velocity of each is reduced to 8 feet per second. A 24-pound ball, moving at the rate of 2000 feet per second, meets a resistance of 800 pounds.

If a body could be projected upwards with the velocity of 36,700 feet in a second, it would never return; and as it receded from the earth, its weight or gravity would diminish. At present, the greatest velocity with which we can project a body, does not exceed 2000 feet per second. A bullet rising a mile above the surface of the earth, loses 1-2000th part of its weight.—*Notes in Science.*

Lieut. Helwig, of Prussia, has invented a process for measuring the time occupied by a ball or bullet in passing through a certain space; by making the ball liberate the works of a time-keeper at the moment when it quits the mouth of the piece, and in making it also stop the time-keeper at the moment when it strikes an obstacle. Thus, he finds that a light body, of the same calibre with the bullet, moves, at the commencement, with much greater velocity than the latter; equal charges being used.

Steam cannon has not yet been found to realize all the formidable expectations which it had raised; but Mr. Perkins has estimated the projectile force of steam to be ten times greater than that of gunpowder, in throwing a ball to a given distance.

While on the subject of fire-arms, we may mention that an ingenious Frenchman proposes to fix a small mirror, 0.47 of an inch in the side, near the mouth-piece, so that the person using it shall see the reflexion of his own eye. In this way it is supposed that very exact aim may be taken; and the experiments made by various officers and sportsmen, are said to encourage the idea that this application may be useful.

Why will a bullet, fired against a door hanging freely on its hinges, perforate the same without agitating it?

Because the impression of the stroke is confined to one single spot, and sufficient time is not allowed for diffusing its action over the extent of the door. A pellet of clay, a bit of tallow, or even a small bag of water, discharged from a pistol, will produce the same effect.

Why is sea-sickness produced on shipboard?

Because man, strictly to maintain his perpendicularity, that is, to keep the centre of gravity always over the support of his body, requires standards of comparison, which he obtains chiefly by the perpendicularity or known position of things about him, as on land; but on shipboard, where the lines of the masts, windows, furniture, &c. are constantly changing, his standards of comparison are soon lost or disturbed. Hence, also, the reason why persons unaccustomed to the motion of a ship, often find relief by keeping their eyes directed to the fixed shore, where it is visible, or by lying on their backs, and shutting their eyes; and, on the other hand, the ill effects of looking over the side of the vessel at the restless waves of the sea.

Sea-sickness, observes Dr. Arnott, also depends partly on the irregular pressure of the bowels among themselves, and against the containing parts, when their inertia, or downward pressure, varies with the rising and falling of the ship.

Reasoning upon the last-mentioned facts, Mr. Pratt,

of New Bond-street, has constructed an elastic or swinging seat, couch, or bed, for preventing the uneasy motions of a ship or carriage; the frame of which is suspended on juribals or joints, turning at right angles to each other; and an elasticity is produced both in the seat or cushion, and in the swinging frames, by the use of spiral metal springs, in the form of an hour-glass. A still more simple preventive was illustrated by Sir Richard Phillips, on his crossing from Dover to Calais, a few years since. He caused an arm-chair to be placed on the deck of the vessel, and being seated in it, he began to raise himself up and down, as on horseback. The passengers laughed at his eccentricity, but before they reached Calais, many of them were sea-sick, whilst Sir Richard continued to enjoy his usual health and vigour. We mentioned this experiment whilst making the same passage in the Royal George steam-boat, about a fortnight since; but no person aboard made the trial of its efficacy, although more than half of the number were sea-sick.

An embrocation has lately been invented, and secured by patent, for preventing or alleviating sea-sickness; this preparation is to be rubbed over the lower end of the breast-bone, and under the left ribs; but we cannot add our own testimony of its efficacy.

Why cannot sure aim be taken with a stone in a sling?

Because the point from which it should depart, cannot be accurately determined.

Why is the pendulum a time-keeper?

Because the times of the vibrations are very nearly equal, whether it be moving much or little; that is to say, whether the arc described by it be large or small.

A common clock is merely a pendulum, with wheel-work attached to it, to record the number of the vibrations; and with a weight or spring, having force enough to counteract the retarding effects of friction and the

resistance of the air. The wheels show how many swings or beats of the pendulum have taken place, because at every beat, a tooth of the last wheel is allowed to pass. Now, if this wheel has sixty teeth, as is common, it will just turn round once for sixty beats of the pendulum, or seconds; and a hand fixed on its axis, projecting through the dial-plate, will be the second hand of the clock. The other wheels are so connected with this first, and the numbers of the teeth on them so proportioned, that one turns sixty times slower than the first, to fit its axis to carry a minute hand; and another, by moving twelve times slower still, is fitted to carry an hour-hand.—*Arnott.*

Why do clocks denote the progress of time?

Because they count the oscillations of a pendulum; and by that peculiar property of the pendulum, that one vibration commences exactly where the last terminates, no part of time is lost or gained in the juxtaposition (or putting together) of the units so counted, so that the precise fractional part of a day, can be ascertained, which each such unit measures.

The origin of the pendulum is traced to Galileo's observation of a hanging lamp in a church at Pisa continuing to vibrate long and with singular uniformity, after any accidental cause of disturbance. Hence he was led to investigate the laws of the phenomenon, and out of what, in some shape or other, had been before men's eyes from the beginning of the world, his powerful genius extracted the most important results.

The invention of pendulum clocks took place about the middle of the seventeenth century; and the honour of the discovery is disputed between Galileo and Huygens. Becher contends for Galileo, and states that one Trifler made the first pendulum clock at Florence, under the direction of Galileo Galilei, and that a model of it was sent to Holland. The Accademia del Cimento also expressly declared, that the application

of the pendulum to the movement of a clock, was first proposed by Galileo, and put in practice by his son, Vincenzo Galileo, in 1649. Huygens, however, contests the priority, and made a pendulum clock before 1658; and he insists, that if ever Galileo had entertained such an idea, he never brought it to perfection. Beckmann says the first pendulum clock made in England, was constructed in the year 1662, by one Tromantil, a Dutchman; but Grignon affirms that the first pendulum clock was made in England, by Robert Harris, in 1641, and erected in Inigo Jones's church of St. Paul, Covent-garden.

Why does the pendulum move faster in proportion as its journey is longer?

Because, in proportion as the arc described is more extended, the steeper are its beginning and ending; and the more rapidly, therefore, the pendulum falls down at first, sweeps along the intermediate space, and stops at last.—*Arnott.*

Why is it extremely difficult to ascertain the exact length of the pendulum?

Because of the various expansion of metals, respecting which no two pyrometers agree; the changeable nature of the atmosphere; the uncertainty as to the true level of the sea; the extreme difficulty of measuring accurately the distance between the point of suspension and the centre of oscillation, and even of finding that centre; also the variety of terrestrial attraction, from which cause the motions of the pendulum are also liable to variation, even in the same latitude. In pursuing his researches, Capt. Kater discovered that the motions of the pendulum are affected by the nature of the strata over which it vibrates.

Why does the force of gravity determine how long the pendulum shall be in falling to the bottom of its arc, and how long in rising?

Because the ball of the pendulum may be considered

as a body descending by its weight on a slope; a change in the force of gravity, therefore, would at once alter the rates of all the clocks on earth.—*Arnott.*

Why is the regulator of a watch merely a pin which bears against the balance-spring?

Because it slides backwards and forwards, so as to shorten or lengthen the part of the spring left free to bend, thus changing the degree of its stiffness; and, as the motion of the pendulum has relation to the force of gravity, so has the motion of the balance-wheel to the stiffness of the balance-spring.

Why do persons walking arm-in-arm, shake each other unless their steps correspond?

Because the centre of gravity in each body comes alternately over the right and over the left foot.

Why are certain metals malleable, or reducible into thin plates or leaves by hammering?

Because their atoms cohere equally in whatever relative situation they happen to be, and therefore yield to force, and shift about among each other, almost like the atoms of a fluid, without fracture or change of property.

Gold is remarkably malleable, for it may be reduced to leaves of the thinness of 282,000 to the inch. For gold-beaters the metal is first formed into rods, these are afterwards rolled or flattened into ribands, the riband is cut into portions, which are extended by hammering to great breadth and thinness, and which being again divided into portions, are hammered and extended to the thinness described.

Why are the steel chisels and tools used for cutting metals so frequently broken?

Because, requiring to be exceedingly hard, they proportionally lose, in regard to the extent of their elasticity. Cast iron, which is much harder than malleable or wrought iron, is very brittle, while soft iron and steel are the toughest things in nature.—*Arnott.*

Why does a smith, by hammering a piece of bar-iron, render it red hot?

Because he thereby compresses the metal. When air is violently compressed, it becomes so hot as to ignite cotton and other substances. An ingenious instrument for producing light for domestic uses has been constructed, consisting of a small cylinder, in which a solid piston moves air-tight: a little tinder, or dry sponge, is attached to the bottom of the piston, which is then violently forced into the cylinder: the air between the bottom of the cylinder and the piston becomes intensely compressed, and evolves so much heat as to light the tinder.—*Lardner.*

Why is the iron rim of a coach wheel heated before putting on?

Because the expansion of the metal occasioned by the heat, facilitates the operation of putting on the iron, while the contraction which follows, brings the joints of the wooden part together; and thus, binding the whole, gives great strength to the wheel.

Why does a bottle of fresh water, corked and let down 30 or 40 feet into the sea, often come up again with the water saltish, although the cork be still in its place?

Because the cork, when far down, is so squeezed as to allow the water to pass in or out by its sides, but on rising it, resumes its former size.

Why do bubbles rise on a cup of tea when a lump of sugar is dropped into it?

Because the sugar is porous, and the air which filled its pores then escapes to the surface of the tea, and the liquid takes its place.

Why are stalactites formed in the interior of caverns?

Because water percolates through their porous sides and roofs, and being impregnated with calcareous and other earths, assumes pendant forms.

Why is there an opening in the centre of the upper stone of a corn mill?

Because through this opening the grain is admitted

and kept turning round between the stones, and is always tending and travelling outwards, until it escapes as flour from the circumference.

Why does a horse in the circus lean to the centre?

Because, when the horse moves round with the performer standing on the saddle, both the horse and rider incline continually towards the centre of the ring, and the inclination increases with the velocity of the motion: by this inclination their weights counteract the effect of the centrifugal force.

Why does water remain in a vessel which is placed in a sling and made to describe a circle?

Because the water, by its inertia of straightness, or centrifugal (or centre-flying) force, tends more away from the centre of motion towards the bottom of the vessel, than towards the earth by gravity.

Why does a spinning top stand?

Because, while the top is perfectly upright, its point, being directly under its centre, supports it steadily, and although turning so rapidly, has no tendency to move from the place; but if the top incline at all, the side of the peg, instead of the very point, comes in contact with the floor, and the peg then becomes a little wheel or roller, advancing quickly, and, with its touching edge, describing a curve somewhat as a skaiter does, until it becomes directly under the body of the top as before. It thus appears that the very fact of the top inclining, causes the point to shift its place, and so that it cannot rest until it come again directly under the centre of the top.—*Arnott.*

Why is a rocking-stone so called?

Because it consists of an immense mass, loosened in some convulsion of nature, and with a slightly rounded base resting on a flat surface of rock below, which is so nearly balanced, that one individual can move or *rock* it. This arises from the rounded body being disturbed from its middle position, and its centre of gravity seeking to return.

Of these rocks, called Loggan or Laggan stones, there are several among the picturesque barriers of the British coast.

Dr. S. Hibbert has very recently described a natural rocking-stone of granite, near the village of Loubeyrat, in the province of Auvergne, France. This stone appears to have been an object of religious worship, for, on the top of it were two figures, a cross, and a pedestal. Under the figures the word *pardon* is traceable, and other letters which probably alluded to the number of days of pardon which the cross gave to the venerator. The natural phenomenon of the rocking-stone probably became an object of superstitious veneration to its neighbourhood, and the figures and cross were the adoring tributes of the natives. Dr. Hibbert, however, thinks that the particular use to which rocking-stones were applied will ever remain in obscurity: "as they are products of every country where loose detached rocks of a particular structure have been submitted to the operation of atmospheric agents, it is to be expected that the fables assigned to their origin would be regulated by the peculiar mythology of the people among whom they have become the object of notice and wonder."

Why have all shot manufactories lofty towers, as seen on the southern bank of the Thames?

Because, in the manufacturing of shot, the liquid metal is allowed to fall like rain from a great elevation, as through these towers, and the cohesive principle gives rotundity to grains of shot. In its descent, the drops become truly globular, and before they reach the end of their fall they are hardened by cooling, so that they retain their shape.

Why does a porter lean forward when carrying a load?

Because his position must be regulated by the centre of gravity of his body and the load taken together. If he bore the load on his back, the line of direc-

tion would pass beyond his heels, and he would fall backwards. To bring the centre of gravity over his feet he accordingly leans forward.—If a nurse carry a child in her arms, she leans back for a like reason.

Why does a young quadruped walk much sooner than a child?

Because a body is tottering in proportion to its great altitude and narrow base. Now, the child has this latter, and learns to walk but slowly, because of the difficulty, perhaps in ten or twelve months, while the young of quadrupeds, having a broad supporting base, are able to stand, and even to move about almost immediately: but it is the noble prerogative of man to be able to support his towering figure with great firmness, on a very narrow base, and under constant change of attitude.—*Arnott.*

Why are the "safety coaches" built with the wheels far apart, and the luggage-receptacles beneath the body?

Because they may have a broader base, and thus be less liable to overturn.

Why do builders use the plummet, or plumb line?

Because, when applied to a body, it is a visible indication of the line of its centre of gravity.

Why do certain structures remain secure, although they have lost their perpendicularity?

Because the line of their centre of gravity remains within the base. The famous tower of Pisa was built intentionally inclining, to frighten and surprise; it is 130 feet high, and overhangs its base 16 feet. At Bologna are two celebrated leaning towers, one of which, the Asinelli, is 350 feet high, and 3½ feet out of the perpendicular. The other, the Garisenda, is about 130 feet in height, and inclines 8 feet from the perpendicular. Montfaucon, the celebrated antiquary, attributes the leaning of these towers to the sinking of the earth. He says, it appears, upon examination, that when the Garisenda tower bowed, a great part of

it went to ruin, because the ground that the inclined side stood on was not so firm as the other, which may be said of all other towers that lean so; for "besides these two here mentioned, the tower for the bells of St. Mary Zobenica, at Venice, leans considerably to one side. So also at Ravenna, I took notice of another stooping tower, occasioned by the ground on that side giving way a little. In the way from Ferrara to Venice, where the soil is marshy, we see a structure of great antiquity leaning to one side. When the whole structure of the Garisenda stooped, much of it fell, as appears by the top."

The Monument, near London Bridge, inclines so much that timid people sometimes doubt its stability, and some years since its fall was a point of discussion. Salisbury and other of our cathedral spires or towers have lost something of their perpendicularity; Chesterfield, in Derbyshire, is proverbial for its zig-zag or wry spire.

The Monument is of the Doric order, and rises from the pavement to the height of 202 feet, containing within its shaft a spiral stair of black marble of 345 steps; the plinth is 21 feet square. It was begun in 1671, but was not completed till 1677; stone being scarce, and the restoration of London and its cathedral swallowing up the produce of the quarries. Mr. Elmes, in his Life of Sir Christopher Wren, the architect, tells us that the Monument was "at first used by the members of the Royal Society for astronomical experiments, but was abandoned on account of its *vibrations* being too great for the nicety required in their observations. This occasioned a report that it was unsafe; but its scientific construction may bid defiance to the attacks of all but earthquakes for centuries." The more recent fear of its instability was therefore only a revival of this alarm; which probably obtained some credence among weak persons, from its being erroneously attributed to Fellows of the Royal Society.

Why is it physically advantageous to turn out the toes?

Because the supporting base of a man consists of the feet and the space between them; and turning out the toes, without taking much from the length of the base, adds a good deal to the breadth.—*Arnott.*

Why do very fat people usually throw back their head and shoulders?

Because, by so doing, they keep the centre of gravity of the body over the base.

SIMPLE MACHINES.

Why have the "simple machines," as the lever, wheel and axle, plane, wedge, screw, and pulley, been long called the "mechanic powers?"

Because they were first used to raise great weights, or overcome great resistances. Hence the common error in supposing that they *generate* force, or have a sort of innate power for saving labour; whereas, neither simple machines nor mechanic powers save labour, in a strict sense of the phrase.

Why, then, are these machines advantageous?

Because they allow a small force to take its time to produce any requisite magnitude of effect. Thus, one man's effort, or any small power, which is always at command, by working proportionally longer, will answer the purpose of the sudden effort of many men, even of hundreds or thousands, whom it might be most inconvenient and expensive, or even impossible to bring together.

Why are there so many vain schemes for perpetual motions, and new mechanical engines of power?

Because the projectors do not understand the great truth, that no form or combination of machinery ever did or ever can increase, in the slighest degree, the quantity of power applied. Hence the futility of supposing that a lever, or great pendulum, or spring, or

heavy fly-wheel, &c. can ever exert more force than has passed into it from some source of motion.—*Arnott.*

THE LEVER.

Why is a beam or rod of any kind, resting at one part on a prop or axis, which becomes its centre of motion, a lever?

Because such a contrivance was first employed to lift (*levare*, Latin) weights.

The lever, in mechanics, compensates power by space, and what is lost in power is gained in time. If the lever be 17 feet long, and the pivot or fulcrum be a foot from one end, an ounce placed on the other end will balance a pound placed on the near end. If, instead of an ounce, we place upon the long end the short end of a second beam or lever, supported by a fulcrum one foot from it, and then place the long end of this second lever upon the short end of a third lever, whose fulcrum is one foot from it; and if we put upon the end of this third lever's long arm an ounce weight, that ounce will move upwards a pound on the second lever's long arm; and this moving upwards, will cause the short end to force downwards 16 pounds at the long end of the first lever, which will make the short end of the first lever move upwards, although 256 pounds be laid upon it. The same effect continuing, a pound on the long end of the third lever, will move up a ton and three-quarters at the short end of the first lever, so that the touch of a child's finger, will move as much as two horses can draw.—*Notes in Science.*

Why did Archimedes reasonably enough say, "Give me a lever long enough, and a prop strong enough, and with my own weight I will move the world?"

Because there is no limit to the difference of intensity in forces, which may be placed in opposition to each other by the lever, except the length and strength of the material of which the levers must be formed. But he would have required to move with the velocity

of a cannon-ball for millions of ages, to alter the position of the earth by the small part of an inch. This feat of Archimedes is, in mathematical truth, performed by every man who leaps from the ground, for he kicks the world away when he rises, and attracts it again when he falls back.—*Arnott.*

Why is a finger caught near the hinge of a shutting door so much injured?

Because the centre of action of the door moves through a space comparatively great, and acts with a great lever-advantage on a resistance placed near the fulcrum of the lever where there is little motion. Children pinching their fingers in this way, or in the hinge of the fire-tongs, where there is a similar action, wonder why the bite is so keen.

Why have pincers or forceps such extraordinary power?

Because they are double levers, of which the hinge is the common prop or fulcrum. Dr. Arnott thus illustrates the advantages of this machine:—In drawing a nail with steel nippers, we have a good example of the advantages of using a tool; 1. The nail is seized by teeth of steel, instead of by the soft fingers; 2. Instead of the griping force of the extreme fingers only, there is the force of the whole hand conveyed through the handles of the nippers; 3. The force is rendered, perhaps, six times more effective by the lever length of the handles; and, 4. By making the nippers, in drawing the nail, rest on one shoulder as a fulcrum, it acquires all the advantages of the lever or claw-hammer for the same purpose.

Why do lofty sails often cause open boats to upset?

Because the mast and sails set upon it are as a long lever, having the sails as the power, turning upon the centre of buoyancy of the vessel as the fulcrum, and lifting the balance or centre of gravity as the resistance.

Why may a boy, who cannot exert a direct force of 50lbs., by means of a claw-hammer, extract a nail, to which half a ton might be suspended?

Because his hand, perhaps, moves through eight inches, to make the nail rise one quarter of an inch. The claw-hammer also proves, that it is of no consequence whether the lever be straight or crooked, provided it produces the required difference of velocity between power and resistance. The part of the hammer resting on the plank, is the fulcrum, or prop.

Why does a combination of levers produce such extraordinary power?

Because if a lever, which makes *one* balance *four*, be applied to work a second lever which does the same, *one* pound at the long arm of the first, will balance *sixteen* pounds at the short arm of the second lever, and would balance *sixty-four* at the short arm of a third such, &c.—*Arnott.*

WHEEL AND AXLE.

Why is motion transmitted through a train of wheel-work by the formation of teeth upon the circumference of the wheels?

Because the indentures of each wheel fall between the corresponding ones of that in which it works, and ensure the action so long as the strain is not so great as to fracture the tooth.

Why is a heavy wheel sometimes used as a concentrator of force, or a mechanic power?

Because, by means of a winch, or a weight, or otherwise, motion or momentum is gradually accumulated in the wheel, and is then made to expend itself in producing some sudden and proportionally great effect.

The coining-presses of the Royal Mint are thus impelled by a fly-wheel, and generally complete a coin by one blow; and they strike, upon an average, 60 blows in one minute; the blank piece, previously pre-

pared and annealed, being placed between the dies by part of the same mechanism. The number of pieces which may be struck by a single die of good steel, properly hardened and tempered, not unfrequently amounts, at the Mint, to between 3 and 400,000. There are eight presses frequently at work for ten hours each day, and each press produces 3,600 pieces per hour; but, making allowances for occasional stoppages, we may reckon the daily produce of each press at 30,000 pieces; the eight presses, therefore, will furnish a diurnal average of 240,000 pieces.

Why is it an error to account the fly-wheel a positive power?

Because, in common cases, it merely equalizes the effect of an irregular force. Thus, in using a winch to turn a mill, a man does not act with equal force all round the circle; but a heavy wheel, fixed on the axis, resists acceleration and receives momentum, while his action is above par, and returns it again while his action is below par, thus equalizing the movement. Again, in circular motion produced by a crank, when by the pressure of the foot on a treadle, we turn a lathe, or grindstone, or spinning-wheel, the force is only applied during a small part of the revolution, or in the form of interrupted pushes, yet the motion goes on steadily, because the turning grindstone, or wheel, or lathe, merely becomes a fly and reservoir, equalizing the effect of the force.

Why is the common winch in principle a wheel?

Because the hand of the worker describes a circle, and there is no difference in the result, whether an entire wheel be turning with the hand, or only a single spoke of the wheel.

Why is a man on a treadmill compelled to keep perpetually moving?

Because, being placed at the circumference of the wheel, his weight turns it, and he must move forward

as fast as the wheel descends, so as to maintain his position continually at the extremity of the horizontal diameter of the wheel.

The invention of the treadmill is, by some persons, said to have been derived from a squirrel in a cylindrical wire cage.

WHEEL CARRIAGES.

Why have wheel carriages been advantageously substituted for sledges?

Because the rubbing or friction, instead of being between an iron shoe and the stones and irregularities of the road, is between the axle and its bush, which have surfaces smoothed and fitted to each other, and well lubricated.

Why does the wheel aid the progress of a carriage?

Because, while the carriage moves forwards, perhaps 15 feet, by one revolution of its wheel, the rubbing part, viz. the axle, only passes over a few inches of the internal surface of its smooth greased bush. Again, the wheel surmounts any abrupt obstacle on the road, by the axle describing a gently rising slope or curve; and by rising as on an inclined plane, and giving to the drawing animal the relief which such a plane would bring.—*Arnott.*

Why are wheels usually made of a dished form, that is, inclining outwards?

Because they thus acquire astonishing strength, indeed that of the arch, as contrasted with the flat or upright wheel; the dished form is farther useful in this, that when the carriage is on an inclined road, and more of the weight consequently falls upon the wheel of the lower side, the inferior spokes of that wheel become nearly perpendicular, and therefore support the increased weight more safely. The disadvantage of these wheels, however, is, that an inclining wheel naturally describing a curved path, the

horses, in drawing straight forward, have to overcome this deviating tendency in all the wheels.—*Arnott.*

Why are axles made of steel, and the parts on which they bear of brass?

Because friction is universally diminished by letting the substances which are to rub each other be of different kinds. The swiftness of a skaiter, it may be observed, depends much on the dissimilarity between ice and steel.

Why are the fore-wheels of carriages smaller than the hind-wheels?

Because they facilitate the turning of the carriage. The advantage of the wheel is proportioned to the magnitude; the smaller wheel having to rise a steeper curve. It is not true, however, according to the popular prejudice, that the large hind-wheels of coaches and waggons help to push on the little wheels before them.—*Arnott.*

From these causes, continues the same ingenious writer, "the difference in performing the same journey of a mile by a sledge and a wheel carriage, is, that while the former rubs over every roughness in the road, and is jolted by every irregularity, the rubbing part of the latter, the axle, glides very slowly over about thirty yards of a smoothed oiled surface, in a gently waving line. It is ascertained that the resistance is thus reduced to 1-100th of what it is for a sledge."

Why do springs not only render carriages easy vehicles on rough roads, but much lessen the pull to the horses?

Because, where there is no spring, the whole load must rise with every rising of the road, and must sink with every depression, and the depression costs as much as the rising, because the wheel must be drawn up again from the bottom of it; but in a spring carriage, moving rapidly along, only the parts below the

springs are moved, in correspondence with the irregularities, while all above, by the inertia of the matter, have a soft and steady advance.—*Arnott.*

Again, springs of carriages convert all percussion into mere increase of pressure: that is to say, the collision of two hard bodies is changed by the interposition of one that is elastic, into a mere accession of weight. It is probable, that under certain modifications, springs may be applied with great advantage to the heaviest waggons.

In surmounting obstacles, a carriage with its load being lifted over, the springs allow the wheels to rise, while the weights suspended on them are scarcely moved from their horizontal level.

Why are "under-springs" so advantageous in very modern carriages?

Because, they insulate from the effects of shocks, all the parts, excepting the wheels and axletrees themselves. When only the body of the carriage is on springs, the horses have still to rattle the heavy frame-work below it, over all irregularities.

Why, in descending a hilly road, is it common to lock or fix one of the wheels of a carriage?

Because, the friction is then increased, and there is less chance of a rapid descent; the horses having then to pull nearly as much as on a level road, with the wheel free.

We have noticed a very effectual mode of "locking" the hind wheels of carriages, on the continent, by screwing a bar transversely, against the outer rim of the wheels; by this means, the wheels may be either partially or wholly locked, according to a powerful screw, in the centre of the bar. This mode is adopted by the Paris diligences; we first noticed it in a Swiss *calèche*, of great strength. The bar is rather unsightly, but our excellence in the construction of wheel-carriages should not lead us always to look for ele-

gance, where convenience is a main point, as in a vehicle for travelling.

Why should a road up a very steep hill, be made to wind or zig-zag all the way?

Because, to reach a given height, the ease of the pull is greater, exactly as the road is made longer.

Why is it important to make roads as level as possible?

Because, a horse drawing on a road where there is a rise of one foot in twenty, is really lifting one twentieth of the load, as well as overcoming the friction, and other resistance of the carriage.—*Arnott.*

THE WEDGE.

Why are cutting instruments, knives, razors, the axe, &c. examples of the wedge?

Because at the same time that we pull them lengthwise, we press them directly forward, against the object. A saw, too, is a series of wedges.

Why does a razor, (if drawn lightly over the hand) dart into the flesh; whereas, if pressed against the hand with considerable force, it will not enter?

Because of the vibration of particles produced by the drawing action, which enables the razor to insinuate itself more easily. We witnessed an example, only a few days since, when a *bon vivant,* in a fit of mischievous ecstasy, seized a pointless table knife, and passed it very lightly down the back of his friend's coat. The injury was not immediately seen, but the cloth proved cut, from the collar to the waist; whereas, had the knife been heavily pressed against the cloth, the coat would have escaped injury, and the gay fellow the expense of his folly.

Why is the wedge so important an agent in the arts and manufactures?

Because it exerts enormous force through a very small space. Thus, it is resorted to for splitting masses

of timber, or stones. Ships are raised in docks, by wedges driven under their keels. The wedge is the principal agent in the oil-mill. The seeds, from which the oil is to be extracted, are introduced into hairbags, and placed between planes of hard-wood. Wedges inserted between the bags, are driven, by allowing heavy beams to fall on them. The pressure thus excited is so intense, that the seeds in the bags are formed into a mass nearly as solid as wood.—*Lardner.*

The details of an extensive oil mill near Garrat are as follow:—A magnificent water-wheel, of 30 feet, turns a main shaft, which gives motion to a pair of vertical stones, raises the driving-beams, and turns a band, which carries the seed in small buckets from the floor to the hopper. The shock on the entire nervous system, produced by the noise of the driving-beams as they fall on the wedges, is not to be described. The sense of hearing for the time is wholly destroyed, and the powers of voice and articulation are vainly exerted. The noise is oppressive, though a rebound, comparatively tuneful, takes place, till the wedge is driven home; but afterwards the blows fall dead, and produce a painful jar on the nerves, affecting the auditor for some hours with a sense of general lassitude.

THE SCREW.

Why does a screw enable a small force to produce such prodigious effects?

Because every turn of the screw carries it forward in a fixed nut, or draws a movable nut along upon it, by exactly the distance between two turns of its thread: this distance, therefore, is the space described by the resistance, while the force moves in the circumference of the circle described by the handle of the screw; and the disparity between these lengths or spaces is often as a hundred or more to one.—*Arnott.*

Why may the screw be called a winding wedge?

Because it has the same relation to a straight

wedge, that a road winding up a hill or tower has to a straight road of the same length and acclivity.

Why is the screw, in some respects, a disadvantageous contrivance?

Because it produces so much friction, as to consume a considerable part of the force used in working it.

Why do mathematical instrument makers mark divisions on their work with the screw?

Because it can easily be made with a hundred turns of its thread in the space of an inch, and at perfectly equal distances from each other. If we suppose such a screw to be pulling forward a plate of metal, or the edge of a circle, over which a sharp-pointed steel marker is placed, which moves up and down perpendicularly, the marker, if let down once for every turn of the screw, will make just as many lines on the plate; but, if made to mark at every hundredth or thousandth of a turn of the screw, which it will do with equal accuracy, it may draw a hundred thousand distinct lines in one inch.

Why may a printing press be said to do the work of fifty men?

Because a solitary workman, with his screw or other engine, can press a sheet of paper against types, so as to take off a clear impression; to do which without the press, the direct push of fifty men would be insufficient; and these fifty men would be idle and superfluous, except just at the instant of pressing, which recurs only now and then. This, and the two preceding illustrations, are almost literally from Dr. Arnott's works, in which the importance of having correct notions on the subject of the simple machines, or mechanical powers, is illustrated by many other familiar examples.

THE PULLEY.

Why is the pulley an advantageous machine?

Because, in such a construction, it is evident that

the weight (let it be supposed ten pounds) is equally supported by each end of the rope, and that a man holding up one end, only bears half of it, or five pounds; but to raise the weight one foot, he must draw up the two feet of rope; therefore, with the pulley, he lifts five pounds two feet, where he would have to lift ten pounds one foot without the pulley.

Why have fixed pullies no mechanical advantage?

Because the weight just moves as fast as the power; yet such pullies are of great use in changing the direction of forces. A sailor, without moving from the deck of his ship, by means of such a pulley, may hoist the sail or the signal flag to the top of the loftiest mast.

Why is the pulley on ship-board called a block?

Because of the block or wooden mass which surrounds the wheel or wheels of the pulley. Hence the machinery for making these pullies is called *block-machinery*. Of that at Portsmouth, invented by Brunel, there is a set of magnificent models in the possession of the Navy Board. They consist of eight separate machines, which work in succession, so as to begin and finish off a two-sheaved block four inches in length.

Mr. Faraday, in a lecture at the Royal Institution in 1829, stated generally, that the block-machinery of Portsmouth, by adjustments, could manufacture blocks of one hundred different sizes; could, with thirty men, make one hundred per hour; and, from the time of its completion in 1804-5, to that day, had required no repairs from Maudslay, the original manufacturer. The total cost was £46,000, and the saving per annum, in time of war, was £25,000, after allowing interest for capital; and paying the expense of all repairs.

Why is a chair or bucket, attached to one end of a rope which is carried over a fixed pulley, used as a fire-escape?

Because a person, by laying hold of the rope on the other side, may, at will, descend to a depth equal to

half of the entire length of the rope, by continually yielding rope on the one side, and depressing the bucket or chain by his weight on the other. In this case the pulley must be attached to some part of the building, or it is recommended that each chamber-floor of a dwelling-house should have a staple fixed near the exterior of a window, to which staple the pulley may be attached by a hook. This is, perhaps, the simplest fire-escape yet proposed, and we need scarcely add, the simpler the means the more likely is it to succeed in extreme danger.

FRICTION.

Why is the friction greater between pieces of the same substance, than between pieces of different substances, with dissimilar grains?

Because, it is supposed, of the roughnesses, or little projections in the former, mutually fitting each other, as the teeth of similar saws would.

"But for friction," observes Dr. Arnott, "men walking on the ground or pavement would always be as if walking on ice; and our rivers, that now flow so calmly, would all be frightful torrents."

Why does the friction of various woods against each other vary?

Because of their different degrees of hardness; the soft woods in general giving more resistance than the hard woods; thus, yellow deal affords the greatest, and red teak the least friction. Soft metals also produce greater friction, under similar circumstances, than those which are hard.—*G. Rennie.*

Why is the friction of surfaces, when first brought into contact, often greater than after their attrition has been continued a certain time?

Because the smoother the surfaces are the less will be the friction, and that process has a tendency to remove those minute asperities and projections on which the friction depends. But this has a limit, and after

a certain degree of attrition the friction ceases to decrease.

Why does smearing the surfaces with unctuous matter diminish the friction?

Because it fills up the cavities between the minute projections which produce the friction.

Why has plumbago, or black lead, been substituted for oil in clocks and chronometers?

Because, when mixed with spirit, it readily adheres to the surface of a steel pivot, as well as to the inside of the hole in which it runs, so that the rubbing surfaces are no longer one metal upon another, but plumbago upon plumbago. These surfaces, by their mutual action, speedily acquire a polish inferior only to that of the diamond, and then the retardation of the machine from friction is reduced almost to nothing, and wear and tear from this cause is totally prevented.

Why are jewelled holes injurious to the pivots of watches and chronometers?

Because, sooner or later, however perfect the polishing may be, the hard substance of the jewel grinds and cuts the steel pivot, and the metallic particles clog the oil.

Why is a peculiar metal requisite for pivot-holes?

Because it must preserve the oil in a fluid state, have little friction with the steel pivot, and be in a degree softer than the pivot, for it is of less consequence that the hole be worn than the pivot. Brass is objectionable, on account of its liability to rust, and gold is too soft for the purpose. Now, an alloy possessing the above requisites has lately been discovered by Mr. Bennett, watchmaker, of Holborn. It consists of pure gold, silver, copper, and palladium, and its small expense, compared with that of jewels, is not its least recommendation.

STRENGTH OF MATERIALS.

Why is a hollow tube of metal stronger than the same quantity of metal as a solid rod?

Because its substance, standing further from the centre, resists with a larger lever. Hence, pillars of cast-iron are generally made hollow, that they may have strength, with as little metal as possible. Masts and yards for ships have been made hollow, in accordance with the same principle.

Why does a plank bend and break more readily than a beam, and a beam resting on its edges, bear a greater weight than if resting on its side?

Because the resisting lever is smaller in proportion as the beam is thinner. Where a single beam cannot be found deep enough to have the strength required in any particular case, as for supporting the roof of a house, several beams are joined together, and in a great variety of ways, as is seen in house-rafters, &c. which, although consisting of three or more pieces, may be considered as one very broad beam, with those parts cut out which do not contribute much to the strength.—*Arnott.*

Why is a beam, when bent by its weight in the middle, very liable to break?

Because the destroying force acts by the long lever, reaching from the end of the beam to the centre, and the resisting force or strength acts only by the short lever, from the side to the centre; while only a little of the substance of the beam on the under side is allowed to resist at all. This last circumstance is so remarkable, that the scratch of a pin on the under side of a plank, resting as here supposed, will sometimes suffice to begin the fracture.—*Arnott.*

Why is a suspension bridge more economical than an ordinary, or insistent bridge?

Because a suspension-bridge varies its curve so as to adapt it to any variation or partial excess in its

load, in consequence of which, the strength of the chains may, with great precision, be adjusted to any required strain, and no more: while, in insistent bridges, the liability of the arch to a fatal derangement of its form by partial or excessive pressure, requires an enormous increase of weight and strength, beyond what is requisite for the mere support of its load, supposing it to be uniformly distributed.—*Ainger.*

Why is iron admirably adapted for the construction of suspension bridges?

Because the greater part of the weight of these bridges arises from the chains themselves, wherefore, the best material for the purpose, is that which has great tenacity with small weight; and iron is at the same time the most tenacious, and, excepting tin, the lightest of the common metals. A square inch of good iron requires about 25 tons to separate it,—and it will not be stretched or otherwise affected, with less than half that weight. Rope bridges, have, however, been introduced, with the advantages of economy and portability, into British India, where a rope-bridge, 160 feet in length, is so light and portable, that it has been several times set up and removed in a few hours.—*Ainger.*

We may here mention, that Mr. Bevan has found the strength or cohesion of cast-iron, to be upwards of 30,000 pounds to the square-inch, though much depends upon the mode of applying the force.

Why is iron best cemented by cast-iron?

Because pure iron, when surrounded by and in contact with cast-iron turnings, and heated, is carbonized very rapidly, so as to exhibit all the properties of steel.

Why is heated air now used in smelting iron?

Because it requires but three-fourths of the quantity of coal requisite, when cold air, that is, air not artificially heated, is employed for that purpose; while the produce of the furnace in iron, is at the same time

greatly increased. It is supposed, that this improvement will accomplish a saving in the cost of the iron, in Great Britain, to the amount of at least 200,000*l.* a-year.—*Jameson.*

Why are piles for bridge-building, driven by great weights being suddenly let fall on them?

Because the body of the workman being too weak, to give a forcible downward push directly, he employs a certain time in carrying a weight up to such an elevation above his work, that when let fall, its momentum may do what is required. Here the continued efforts of the man in lifting the weight, to a height of perhaps thirty feet, may be just sufficient to sink into the earth one inch; and the continuance has, therefore, balanced forces, which are to each other in intensity, as thirty feet to an inch.—*Arnott.*

Why does an ill-built bridge generally flatten in the arch?

Because the builder has not sufficiently attended to the effect of the horizontal thrust of the arch on its piers. Each arch is an engine of oblique force, pushing the pier away from it. In some instances, one arch of a bridge falling, has allowed the adjoining piers to be pushed down towards it, by the thrust, no longer balanced, of the arches beyond; and the whole structure has given way at once, like a child's bridge, built of cards.—*Arnott.*

The principle of bridge-building is beautifully illustrated by the small toy-models; the stones being represented by separate pieces of wood, which the juvenile architect is required to form into an arch, or arches. It could be wished that the above and such scientific toys were better appreciated in England. They seem only to suit the caprice of the moment. Thus, the Chinese, Indian, and other puzzles, were but the favourites of a year, and Dr. Brewster's splendid kaleidoscope was less understood, and more abused, than any modern discovery.

Why do the great domes of churches resemble simple arches?

Because they have strength on the same principle, being in general, strongly bound at the bottom, with chains and iron bars, to counteract the horizontal thrust of the superstructure; this binding, in truth, resembling a pier all round. St. Peter's at Rome, and St. Paul's in London, are fine examples; as is also the large fir roof of the Basilica of St. Paul's. At Rome, the trusses are double, and placed fifteen inches asunder, which gives it, probably, more stability than if they were strapped and bound into single masses.

Why is the Gothic or pointed arch so universally admired for its strength and beauty?

Because it bears the chief weight on its summit or key-stone. Bishop Warburton, in his *Divine Legation*, supposes the Gothic arch to have been taken from an avenue of trees. Hence the "high o'er arching groves," and "the verdant portico of woods," of Milton and Thomson; Cowper says,

——"The grove receives us next,
Between the upright shafts of whose tall elms," &c.

In Betchworth Park, Surrey, is an avenue of gigantic elms: its length is 350 yards, resembling the *nave of a cathedral;* the trees form, on the outside, a vast screen or wall of verdure; within, the branches, meeting at a great height in the air from the opposite rows, form "Gothic arches," and exclude every ray of the meridian sun.

Why does the arched form bear pressure so admirably?

Because, by means of it, the force that would destroy is made to compress all the atoms or parts at once, and nearly in the same degree. The whole substance of the arch therefore resists, almost like that of a straight pillar under weight, and is nearly as strong.

The strength of the arched form is exemplified in the well-known experiment of bottles, containing only

air, and corked, being let down into the sea, and drawn up filled with water, and the cork driven in below the neck of the bottle. Thus, if the bottle have flat sides, and be square-bottomed, it will be broken by the pressure; but, if it be round, it will be more likely to resist the pressure, and have the cork forced in. The shape, in this case, is conducive to strength,—partaking of the qualities of an arch.

It is not known at what period the arch was invented, but it was comparatively in modern times. The hint was probably taken from nature; arched rocks being among the interesting wonders of the earth. At Lewis, in the Hebrides, is a stupendous specimen of curved gneiss, (a primitive rock, in which metals mostly abound) which has the bold symmetry of the Saxon arch. It is a matter of surprise, that, with so many specimens in nature, the arched form was not adopted earlier. The human skull is another specimen of the arched form; and the strength thus obtained, explains the unseeming impossibility of breaking an egg by pressing it endwise between our hands: again, what hard blows of the spoon or knife are often requisite to penetrate the shell. "The weakness of a similar substance, which has not the arched form, is seen in a scale from a piece of free-stone, which so readily crumbles between the fingers."

It is generally admitted, that the early Greeks were unacquainted with the principle of constructing the arch, and that neither the Indians nor Egyptians were acquainted with it. In Egypt, however, the monuments of which country are more ancient probably than any other on the face of the globe, the form of the Roman arch was well known, as is attested by remains of passages *cut out* in stone. Among the ruins of Thebes, sun-dried brick-buildings have been found to contain *constructed* arches, which may be referred to an age coeval with Thebes itself, as well as to any later period. In the oldest buildings of the Hairan, are round

and pointed arches, cut out and constructed; so that the arch may be carried back to the earliest period at which these fertile plains were first peopled by a race dwelling in houses; and this we know to have been as early as the time of Job, or even before, as, in his day, his sons and daughters feasted luxuriously in *houses*. It is not, however, to be necessarily inferred from this, that the Romans borrowed the form of the arch, or the principle of its construction, from the East, since these might both have existed in this quarter at an early period, and yet have been discovered in Italy at a much later date, without any knowledge of its existence elsewhere.—*Abridged from Buckingham's Travels.*

Why is the invention of architecture attributed to the Egyptians?

Because the Egyptian capitals are a complication of orders in one mass, which, if divided, would produce numerous hints for new ideas. Thus, from the *lotus*-leaved capitals, it will be acknowledged, that the *Doric* and *Corinthian* orders have been extracted. The *Ionic*, also, is believed to have originated in Egypt; from the remains of thé small temple of Isis, in the island of Philæ. Isis, is the Io of the Greeks, from whom the name of Ionic was no doubt derived; and it is very probable, that he who introduced the order gave it that name, as having been taken from the temple of the goddess. Such is the hypothesis of Belzoni, respecting three of the five orders; the remaining two are thus explained:—the *Tuscan*, by inspection, and comparison of its component elements, will be found almost the same as the Doric, and is evidently derived from it; and the *Composite* is formed of the proportions and enrichments of the Corinthian order, and the angular volute of the Ionic.

Why did the Egyptians erect such stupendous monuments as the pyramids?

Because, it is conjectured, of the policy of the

Egyptian rulers, whose plan to prevent the evils of over-populousness, was, to accustom the lower orders to a spare diet, and employ them in the construction of huge edifices, destined for tombs, or the temples of religion. Hence, the pyramids and excavated temples, which still excite the wonder of the world, and prove what may be effected by the aid of the simplest machinery,—with time, numbers, and perseverance.—*Belzoni.*

Why do the more ancient Egyptian monuments exceed the later in design and execution?

Because, among the Egyptians, every thing advanced to a certain point of perfection;—there stopped, never to advance, but rather to recede.—*Belzoni.*

Why are light-houses built of a circular form?

Because, partaking of the properties of the arch, it best enables them to withstand the fury of tempests, from every quarter. The Eddystone light-house, built by Mr. Smeaton, the English engineer, is a splendid triumph of this principle.

Why were mirrors first used for reflecting light-houses?

Because of the following trivial circumstance.

At a meeting of a society of mathematicians, at Liverpool, one of the members proposed to lay a wager, that he would read a paragraph of a newspaper, at ten yards distance, with the light of a farthing candle. The wager was laid, and the proposer covered the inside of a wooden dish with pieces of looking-glass, fastened in with glazier's putty,—placed his reflector behind the candle, and won his wager. One of the company marked this experiment with a philosophic eye. This was Capt. Hutchinson, the Dock-master, with whom originated the Reflecting Light-houses, erected at Liverpool, in 1763.

The revolving lights, as at Calais, are an improvement upon this invention. Lieutenant Drummond's

ingenious application of ignited lime to the illumination of light-houses, a brilliant discovery of the present day, has been already noticed.*

Why is hempen-rope preferable to iron-chain for the scale of a weighing beam?

Because the rope resists a greater weight falling into the scale than is resisted by the chain, and is altogether stronger than the chain; the hemp yields by its elasticity, and continues its resistance through a considerable space and time,—and thus at last gradually overcomes the momentum; while the iron, by not yielding, either requires to be strong enough to stop the mass suddenly, or breaks.

Why are chain cables stronger than those of hemp or rope?

Because the chain, by its weight, hangs as a curve or inverted arch in the water, while the rope being nearly of the weight of water, is supported by it, and becomes almost a straight line from the anchor to the ship; and when a great wave dashes against the ship, the straight rope can only yield by the elasticity of its material, and, comparatively, therefore, a little way; but the bent chain will yield until it be drawn nearly straight, and by this greater latitude of yielding, and consequent length of resistance, it will stand a greater shock.—*Arnott.*

Why is British oak more durable than that of North America?

Because variable weather, as in Britain, conduces to firmness, whereas, the hot summers of North America impoverish its growth.

Why is steaming prejudicial to timber?

Because the heat and moisture together, always weaken that constituent principle of the timber, upon which its strength and durability in a great measure depend.

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* See POPULAR CHEMISTRY, page 50

Why is steaming indispensable for ship-building?

Because the planks cannot be otherwise curved or twisted, as in the bends of the hull of the vessel.

To give an idea of the enormous quantity of timber necessary to construct a ship of war, we may observe, that 2,000 tons, or 3,000 loads, are computed to be required for a seventy-four. Now, reckoning fifty oaks to the acre, of 100 years standing, and the quantity in each tree at a load and a half, it would require forty acres of oak-forest to build one seventy-four; and the quantity increases in a great ratio, for the largest class of line-of-battle-ships. A first-rate man-of-war requires about 60,000 cubic feet of timber, and uses 180,000 pounds of rough hemp, in the cordage and sails for it. The average duration of these vast machines, when employed, is computed to be fourteen years. It is supposed, that all the oaks now in Scotland, would not build two ships of the line. In Sweden, all the oak belongs to the king, or the proprietors of estates can only dispose of it to government; so that, when not wanted for the navy, it is often left to decay, and indeed, is generally much neglected.

Why is teak wood superior to oak?

Because it is stronger and more buoyant. Its durability is more decided; and, unlike the oak, it may be put in use almost green from the forest, without danger of wet or dry rot. The oak contains an acid which corrodes and destroys iron; the teak, on the contrary, possesses an essential oil which preserves iron.

Why are beech and elm good timber for the lower keels of ships, and the piles of bridges and harbours?

Because both, when under water, are extremely durable; though neither stand the effects of the atmosphere.

Why is fir preferable to oak for common building?

Because it is lighter, far more elastic, more easily worked, straighter, and of much greater length. The

best that comes in the form of deals, is from Christiana and Frederickstadt, chiefly on account of the vast superiority of the saw-mills there.

Why was chestnut used in ancient roofs?

Because of its lightness and durability. The largest roof of the ancient construction is that of Westminster Hall, which is of chestnut. The support of every piece of timber is apparent; and the only strain which appears directly across the timber is on the boards and rafters between the great trusses; and it does not appear to be in the least decayed, although constructed four hundred and fifty years since.

COALS AND GUNPOWDER.

Why are coals so productive of grand mechanical effects?

Because of their great hidden powers, which we can at pleasure call into action. Thus, it is well known to modern engineers, that *there is virtue* in a bushel of coals, properly consumed, to raise seventy millions of pounds weight a foot high. This actually is the *average* effect of an engine at this moment working in Cornwall. The Menai Bridge, one of the most stupendous works of art that has been raised by man in modern ages, consists of a mass of iron not less than four millions of pounds in weight, suspended at a medium height of about 120 feet above the sea. The consumption of seven bushels of coal would suffice to raise it to the place where it hangs.

The great pyramid of Egypt is composed of granite. It is 700 feet in the side of its base, and 500 in perpendicular height, and stands on eleven acres of ground. Its weight is, therefore, 12,760 millions of pounds, at a medium height of 125 feet; consequently, it could be raised by the effort of about 630 chaldrons of coal, a quantity consumed in some foundries in a week.—*J. F. Herschel.*

Why is gunpowder another important source of mechanical power?

Because of the tremendous force which it exercises in certain operations, as blasting rocks, &c. in the progress of mechanical works. Thus, in the progress of cutting the Delaware Canal, four kegs of gunpowder, containing about 100lb. were, in 1829, used for a single blast, and had the effect of rending in pieces more than 400 cubic yards of rock.*

Yet it is only when we endeavour to confine gunpowder, that we get a full conception of the immense energy of that astonishing agent. In Count Rumford's experiments, twenty-eight grains of powder in a small cylindrical space *which was just filled*, tore asunder a piece of iron which would have resisted a strain of 400,000 pounds, applied at no greater mechanical disadvantage.

BALANCES.

Why are we enabled to determine the relative weight of a body, compared with the weight of another body, assumed as a standard, by means of the balance?

Because the balance consists of an inflexible rod or lever, called the beam, furnished with three axes; one, the fulcrum, or centre of motion, situated in the middle, upon which the beam turns, and the other two near the extremities, and at equal distances from the middle. These last are called the points of support, and serve to sustain the pairs or scales. These points and the fulcrum are in the same right line, and the centre of gravity of the whole should be a little below the fulcrum, when the position of the beam is horizontal. The arms of the lever being equal, it follows,

* By way of parallel with this effect, though produced by different means, we may mention that in 1825 there was opened in Cochin-China, a canal twenty-three miles long, eighty feet wide, and twelve feet deep. It was begun and finished in six weeks, although carried through large forests, and over extensive marshes. Twenty thousand men were at work upon it day and night; and it is said that seven thousand died of fatigue

that if equal weights be put into the scales, no effect will be produced on the position of the balance, and the beam will remain horizontal. If a small addition be made to the weight in one of the scales, the horizontality of the beams will be disturbed; and, after oscillating for some time, it will, on attaining a state of rest, form an angle with the horizon, the extent of which is a measure of the delicacy or sensibility of the balance.

Why should not the weights of a balance be touched by the hand?

Because that would not only oxydate the weight, (or cause it to rust) but by raising its temperature, it would appear lighter when placed in the scale-pan, than it should do, in consequence of the ascent of the heated air. For the large weights, a wooden fork or tongs should be employed; and for the smaller, a pair of forceps made of copper; this metal possessing sufficient elasticity to open the forceps on their being released from pressure, and yet not opposing a resistance sufficient to interfere with that delicacy of touch, which is desirable in such operations.—*Kater.*

Why does one weight alone serve to determine a great variety of others, by the steelyard?

Because the steelyard is a lever, having unequal arms, and by sliding the weight along the longer arm of the lever, we thus vary its distance from the fulcrum, taken in a reverse order; consequently, when a constant weight is used, and an equilibrium established, by sliding this weight on the longer arm of the lever, the relative weight of the substance weighed, to the constant weight, will be in the same proportion as the distance of the constant weight from the fulcrum is to the length of the shorter arm.

Why is the spring steelyard in very general use?

Because of its portability; as a spring that will ascertain weights from one pound to fifty, is contained

in a cylinder only 4 inches long, and $\frac{3}{4}$ inch diameter. To use this instrument, the substance to be weighed is suspended by a hook, the instrument being held by a ring passing through the rod at the other end. The spring then suffers a compression, proportionate to the weight, and the number of pounds is indicated by the division on the rod, which is cut by the top of the cylindrical tube.—*Kater.*

The dial weighing machine is a modification of the same principle, connected with hands on a dial or clock-face to denote the weight.

WATER.

Why do water-wheels vary in their construction?

Because of the different ways in which the mechanical force of the liquid is intended to be applied.

Why are certain of these wheels called overshot?

Because the water by which they are impelled descends from its level to a lower one; its weight during the descent (falling, as it were, *over* the wheel) causing the wheel to turn. That this may be possible, it is only necessary that there should be a sufficient supply of water at the superior level, and that there should be a means of carrying it off after its descent, so as to prevent by its accumulation, the equalisation of the two levels. Hence the necessity of flood-gates in a mill course. On the circumference of the wheel the weight of the water is made to act in its descent, in a direction as nearly as possible at the right angles to the spokes, or radii; this pressure, however, acting only at one side of the wheel; thus making the wheel revolve, and communicate motion to its axis; and this motion being transmitted by wheel-work, and other contrivances, to the machinery which it is required to work.

Why are other wheels called undershot?

Because the flat or float boards placed at equal distances on the rim, and projecting from it, in direc-

tions diverging from its centre, are intended to receive the impulse of the water as it passes *under* the wheel. The wheel is thereby caused to revolve in the direction of the stream, with a force depending on the quantity and velocity of the water, and the number, form, and position of the float-boards.

The *breast* wheel partakes of the nature of the overshot and undershot wheels; like the latter, it has float-boards; but, like the former, it is worked more by the weight of water than by its impulse.

The *power of water* on wheels may be thus illustrated. If 100 gallons per minute be equal to a certain power with one foot of fall, one gallon per minute will perform the same work with 100 feet of fall.*

Why is the hydrostatic or Bramah's press, another example of the mechanical agency of water?

Because water, in common with all fluids, possesses the power of transmitting pressure equally in every direction. In this instance, too, it is materially aided by the mechanical efficacy of the lever.

Pascal demonstrated this principle and its advantages, by fixing to the upper end of a cask set upright, a very long and narrow cylinder. In filling the barrel, and afterwards the cylinder, the simple addition of a pint or two of water, which the latter was capable of containing, produced the same effect as if the cask, preserving its diameter throughout, had its height increased by the whole length of the cylinder. Thus, the increase of weight of a pint or two of water, was sufficient to burst the bottom of the hogshead, by the immense augmentation of pressure it occasioned. Now, if we suppose the water removed from the cylinder of

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* The mechanical force of running water is tremendous. During the great storm and flood in Scotland, in 1829, the river Don forced a mass of 400 or 500 tons of stones, many of 200 or 300 pounds weight, up an inclined plane, rising 6 feet in 8 or 10 yards. A stone of 3 or 4 tons, was likewise moved out of a deep pool of the river, 100 yards from its place.

narrow dimensions, and replaced by a solid of equivalent weight, such as a piston, it is evident that the pressure must remain everywhere the same. Again, if we suppose the weight of the piston to be multiplied by the power of a lever acting on its shaft, the pressure will be proportionally augmented, so as to produce on the bottom of the cask a pressure equivalent to an enormous weight, with the exertion of very little primitive force on the piston.—*Notes in Science.*

This property of liquids also enables us with great facility to transmit the motion and force of one machine to another, in cases where local circumstances preclude the possibility of instituting any ordinary mechanical connexion between the two machines. Thus, merely by means of water-pipes, the force of a machine may be transmitted to any distance, and over inequalities of ground, or through any other obstructions.

Why is the hydrostatic press more advantageous than that worked by a screw?

Because between solids and fluids there is little or no friction; and, accordingly, in the hydrostatic press no force is lost by friction, except what is necessary to overcome the friction of the pistons in the cylinders. The loss of power in the screw, by means of friction, has already been explained at page 32.

ANIMAL STRENGTH.

Why does the rate of steam carriages surpass the utmost stretch of animal power?

Because the machine by which they are propelled, unlike any animal, rolls along unimpeded in any degree by the speed of its own motion.

According to some experiments, recently made by Mr. Bevan, to determine the actual force of draught of carriages upon common roads, it appears that five horses will draw with equal ease the same load upon a good hard turnpike road, as thirty-three horses can

do upon loose sand. Or, if we assume the value of draught, upon a well-formed road in good condition, at 6*d.* per ton per mile, the equivalent price of draught will be upon hard turf, 7½*d.*; hard loam 9½*d.*; ordinary bye-road, 1*s.* 7*d.*; newly gravelled road, 2*s.* 2*d.*; loose sandy road, 3*s.* 1*d.*—*Philos. Mag.*

The power of some dogs is very extraordinary. Nine Esquimaux dogs, belonging to Captain Lyon, dragged 1611 pounds one mile (1760 yards) in nine minutes, and worked in this manner for seven or eight hours a day.

Why is it so disadvantageous to propel boats on canals by means of horses?

Because the expenditure of animal strength takes place in a far greater proportion than the increase of speed. Thus, if a horse of a certain strength is barely able to transport a given load ten miles a day for a continuance, two horses of the same strength will be altogether insufficient to transport the same load twenty miles a day. To accomplish that a greater number of similar horses would be requisite. If a still greater speed be attempted, the number of horses necessary to accomplish it would be increased in a prodigiously rapid proportion. This will be evident, if the extreme case be considered, viz., that there is a limit of speed which the horse, under no circumstances, can exceed. In an ordinary canal one horse with a boat will be sufficient for every thirty tons.

Why is a man better enabled than a horse to carry a weight up a steep hill?

Because the peculiar disposition of the limbs of a man, renders him well fitted for this species of labour; whereas it is the worst method in which a horse can be employed. It has been observed that three men climbing a hill, loaded with 100lbs. each, will ascend with greater speed than one horse carrying 300lbs.

The average value of human strength, considered

as a mechanical agent, has been variously estimated. Desaguliers considers that a man can raise the weight of 550lbs. ten feet high in a minute, and continue to do so for six hours. Smeaton, however, thinks that six good English labourers will be required to raise 21,141 solid feet of sea-water to the height of four feet in four hours. In this case, they will raise very little more than six cubic feet of fresh water each, ten feet high in a minute. The labourers whom Smeaton supposes to execute this work he considers to be equal to twice the number of ordinary men. It would, therefore, perhaps, be a fair average value of a man's work to estimate it, for a continuance, at half a hogshead of water raised through ten feet in a minute.

The efforts of men differ with the manner in which these efforts are employed. It has been shown by Mr. R. Buchanan, that the same quantities of human labour employed in working a pump, turning a wheel, ringing a bell, and rowing a boat, are as the numbers 100, 167, 227, and 248. The most advantageous manner of applying human strength is in the art of rowing.—The strength of an ordinary man walking in an *horizontal* direction, and with his body inclining forward, is, however, only equal to 27lb., and it is known by experience, that a horse can draw *horizontally* as much as seven men.

Why is the power of a steam-engine expressed in horse power?

Because this mode was introduced when steam engines first began to supersede horse mills, when the manufacturer naturally inquired how many horses a steam-engine would dispense with. Hence the expression is more practical than scientific.

The power of a horse is understood to be that which will elevate a weight of 33,000* pounds, the height of

* Another estimate reduces this to only 22,000 pounds, raised one foot high in a minute, equivalent to 100 pounds in two miles and a half per hour.

one foot in a minute of time, equal to about 90 pounds at the rate of four miles an hour. This is a force greater than that exerted by a common cart horse, which is not estimated at more than 70 pounds: that is to say, that a horse harnessed to a cart, weighing, with its load, forty cwt. or two tons, and drawing on a level road at the rate of four miles an hour, makes use of the same force, as if his traces, instead of being fastened to a cart, were passed over a pulley, and lifted perpendicularly a weight of 70 pounds.

A steam-engine consumes about 20 feet of steam per minute for every horse-power.—*Notes in Science.*

RAILWAYS.

Why are railways more economical than ordinary roads?

Because, to drag a loaded waggon up one inconsiderable hill, costs more force than to send it thirty or forty miles along a level railway; and the conclusion follows, that although the original expense of forming the level line might materially exceed that of making an ordinary road, still, in situations of great traffic, the difference would soon be paid by the savings; and when once paid, the savings would be as profit ever after.—*Arnott.*

By way of illustrating the great economy of machinery, we may observe, that in Sedjah, (where the Arabs obtain fine millstones) "their unskilfulness and want of proper implements adapted to their labour, with the expense of carriage from the quarry to the place of sale, each stone requiring a single camel, (wheel carriages and good roads being entirely unknown) occasion an advance above the prime cost at which they might be hewn in England, of at least 500 per cent, each pair of stones costing from ten to twenty pounds sterling."—*Buckingham's Travels.*

Why has a suspension railway been represented as more advantageous than a ground railroad?

Because the former takes a straightforward point from one town to another, without regard to the surface of the country over which it has to go, whether rising or falling, a perfect level being obtained by varying the heights of the pillars or piers which support the railway; while its height above the ground allows agriculture and commerce to go on under it without interruption. The cost of a suspension railway has been estimated at £1,400 per mile, which is about two-thirds less than the average expense of a ground railroad. Models of a suspension railway, and carriages adapted to it, were recently exhibited in London, by Mr. Maxwell Dick, their inventor.

Why is wrought iron preferable to cast iron for railways?

Because by wrought iron rails we reduce the number of joints; the difficulty of making the rails perfectly even at the joints, has also contributed much towards the introduction of wrought iron.

Edge railways were first made of wood, near Newcastle; these were next covered with plates of wrought iron in the parts most likely to wear. Cast iron was subsequently introduced there and elsewhere; and wrought iron is now being very generally substituted for the cast.

Why has it been proposed to transfer the power of fixed and cheap first movers to locomotive carriages, &c. travelling on common turnpike roads?

Because the power of a steam-engine, moving with the locomotive carriage, is very expensive when compared to an equal power obtained by a large ordinary fixed engine, a wind or water mill, or other common first mover. Mr. Fordham, the originator of this plan, proposes to condense air into cylinders, and then to use this condensed air as the motive force.

Why has the application of steam to land carriages been so long a favourite project with mechanicians?

Because the transition from the one element to the other appears, at first view, to be so simple and easy: the same mechanical process which turns the paddle wheels of a vessel in the water, would seem quite adequate to impart a similar motion to the wheels of a carriage on land. So early as the year 1769, Mr. Watt mentions the practicability of applying it to domestic improvement, though it does not appear that Watt gave motion to a carriage. Symington, who claims the original invention of the steam-boat, had previously contrived a similar application for the impelling of carriages; and actually exhibited, in the year 1787, in Edinburgh, the first model of a steam-carriage that was perhaps ever seen. Hence we may conclude that the repeated failures in the plan have not been occasioned so much by the want of practical skill, as by some radical difficulty which had not been sufficiently adverted to.

The steepest inclined planes which, as far as we are aware, locomotive engines have attempted to surmount, are those on the Bolton and Leigh railway, in Lancashire. One of these planes is a mile and a half long, and rises one yard in thirty. Up the former of these the *Sans Pareil* engine ascended, drawing after her her tender carriage with coal and water, two waggons loaded with iron, and a carriage with passengers, making a gross weight drawn, of about fifteen tons; with which she moved at the rate of nine miles per hour. Up the steepest plane (rising 1 yard in 30) she drew her tender, and one carriage with passengers, the gross weight being about four tons fifteen cwt., with which she ascended at a speed of from nine to eleven miles per hour; each of these performances being equal to about sixty-five tons drawn on a level. —*Note to Quarterly Review.*

Why was the difficulty just adverted to greater in the land carriage than in the boat?

Because of the resistance to the progress of the

carriage by the inequalities and other obstructions on the roads. It is not here as in navigation, where the most enormous weights are buoyed up by the liquid element, without increasing, in the same degree, the resistance to the vessel. Every additional load to a land carriage creates an additional resistance, arising from inertia, friction, and other such impediments, exactly in proportion to its weight.—*Quarterly Review.*

Why does the progress of locomotive engines on railroads appear so extraordinary?

Because we compare their moving power and resistance with other moving powers and resistances to which our minds have been familiar. To the power of a steam-engine, in fact, there is no practical limit; the size of the machine and the strength of the materials excepted. This is compared with agents to whose powers nature has not only imposed a limit, but a narrow one. The strength of animals, as just shown, is circumscribed, and their power of speed still more so.

Why are railways usually laid down in double lines?

Because carriages, moving in opposite directions, may pass each other without interfering. In the same manner, a third or fourth, or more lines, may be laid down, if necessary; and, between them are communications, at intervals, by which any carriage overtaking another in the same track, may turn aside to one of the adjacent lines, and pass it, without stopping either.

The Chevalier Baader, of Munich, has contrived a plan for this purpose, so that no siding planes nor turning plates are necessary; and turning can be performed almost as quickly and as easily as upon a common turnpike road. He has also constructed waggons, so that upon a dead level, the power of one horse is sufficient to draw with ease, and at a good pace, a load of from twelve to fourteen tons, when

divided amongst several carriages linked together. The Chevalier also states that he has discovered a new principle, by which the power and motion of stationary steam-engines, and other machines, established at considerable distances apart, along the railroads, and working without interruption, can be imparted to any number of loaded carriages passing upon the railway, from one steam-engine or machine to another, without the employment of drag-ropes or chains, or, indeed, of any intermediate apparatus; and yet with any reasonable degree of velocity. These extraordinary statements are made in the *Franklin Journal*, 1830.

Why are the resistances which occur on a railway rather diminished than increased by velocity of motion?

Because the quicker we move along, there is the less time for the retarding force to operate; by increasing the rapidity, we escape, in some degree, from its influence, and may really be urged forward with a smaller amount of force, provided the machinery be adapted to so quick a rate of motion.—*Quarterly Review.*

Why has a tubular boiler, or one composed of welded iron pipes, been adopted by Mr. Gurney, in his steam carriage?

Because, even from the bursting of such a boiler, there is not the most distant chance of mischief to the passengers. Instead of being, as in ordinary cases, a large vessel closed on all sides, with the exception of the valves and steam conductors, which a high pressure or accidental defect may burst, Mr. Gurney's boiler consists of a horse-shoe of pipes, and the space between them is the furnace; the whole being enclosed with sheet-iron. The only possible accident would therefore be the bursting of one of these pipes, and a temporary diminution of the steam power, according to the proportion the pipe bears to the whole boiler.

Why were two steam cylinders introduced instead of one, in the early locomotive engines?

Because, by acting at different parts of the wheels, they produced a much more regular motion than formerly, and rendered unnecessary a fly-wheel, which had hitherto been used.

Why were the early engines so injurious to the railway?

Because of their enormous weight, amounting to six or eight tons, exclusive of the tender for water and fuel. The Rocket, lately constructed by Messrs. Stephenson and Co. of Newcastle-upon Tyne, weights only four tons five cwt.; and the Novelty, by Messrs. Braithwaite and Ericson, weighed but two tons fifteen cwt.

Why is a low chimney desirable, as in the Novelty engine?

Because it enables the proprietors of the railway to reduce the height of all the bridges under which the engines must pass, in crossing any of the public as well as private roads. It will admit of a deduction of seven or eight feet from the height of the mason-work in every such bridge. What a saving, then, must this produce in the original cost of a railway, through a cultivated country, where these bridges must frequently occur.—*Quarterly Review.*

Why is it no longer necessary to lay out railways on a perfect level?

Because engines have already been made to draw carriages up inclined planes rising one yard in thirty, and one yard in seventy-two, at the rate of from nine to eleven miles an hour. Hence we are enabled to vary the levels, and adapt them to the undulating nature of the country through which the line passes.

Why are steam carriages for the conveyance of goods, expected to improve the internal intercourse of this country in a very important degree?

Because it is calculated that the carriage of goods, which is now about 9*d.* or 10*d.* a ton per mile, by land, would thus be reduced to 2*d.*; and, in point of

speed, one day would do the work of four. The heaviest commodities, such as corn, potatoes, coals, &c. would bear the expense of carriage for a hundred miles; the expense of living in great towns would be reduced, and the price of raw produce would rise in remote parts of the country.

Again, "with so great a facility and celerity of communication, the provincial towns of an empire would become so many suburbs of the metropolis, or rather, the effect would be similar to that of collecting the whole inhabitants into one city."—*Scotsman Newspaper.*

Another great source of revenue and of trade, from this improved mode of intercourse, (observes the *Quarterly Review*) would arise from the conveyance of those fine goods, parcels of value, and all light articles, where speed and certainty are required; and which are now sent, at great expense, by coaches. In this manner the seats of the various finer and lighter manufactures would be brought almost into immediate contact with the great markets for their disposal. A merchant in London, on receiving any particular order, might send either to Nottingham, to Birmingham, or to Sheffield, or even to Manchester or Leeds, and have the goods in his shop the next or following day, at an expense not exceeding 1*s.* 6*d.* or 2*s.*

Lastly, the rapid circulation of intelligence. The mails might travel safely at 25 miles an hour, and letters be conveyed between London and Edinburgh, a distance of 400 miles, in 18 hours; so that an event happening in London, would be known in Edinburgh the same day.

As an example of the difficulties of internal navigation, before the introduction of steam for that purpose, it may be mentioned that, on the great river Mississippi, which flows at the rate of five or six miles an hour, it was the practice of the boatmen, who brought down the produce of the interior to New Orleans, to

break up their boats, sell the timber, and afterwards return home slowly by land; and a voyage up the river from New Orleans to Pittsburgh, a distance of about two thousand miles, could hardly be accomplished, with the most laborious efforts, within a period of four months. This voyage is now made by steam-boats, with ease, in 15 or 20 days; and at the rate of not less than five miles an hour.

Why would steam be advantageous for propelling ploughs and other agricultural implements?

Because, independently of the saving of horses and their food, the farmer would never be obliged to work his soil, but when it was in a proper condition for that purpose. Mr. Loudon thinks that to apply steam successfully to agriculture, the engineer ought not to seek for a new implement, but simply for a convenient locomotive power for propelling the implements already in use, modified so as to suit the new impelling power.

Why are the locomotive engines so advantageous for the conveyance of passengers?

Because they admit a rate of speed that would be entirely inconsistent with safety, even although it were practicable to attain it with animal power. It would be still imprudent, however, to adopt the utmost rate of thirty miles, because such an unusual rate of velocity, surpassing that of the swiftest horse, would be alarming, if it were not dangerous. At the rate of twenty miles an hour, however, it might be perfectly practicable to travel with the utmost safety and comfort. The economy of the plan may be illustrated as follows:—Between Liverpool and Manchester, we may safely estimate the number of passengers every day at 400 each way, and the average fare to be about seven shillings each; the daily expenditure will amount, in this manner, to about 280*l.* By the use of steam-coaches, the fares will be reduced to two-shillings

and sixpence, and would thus amount only to 100*l.* per day, making a daily saving of 180*l.*, or upwards of 60,000*l.* per annum.

The expense of the Liverpool and Manchester Railway, is now estimated at upwards of 20,000*l.* for each mile; the whole cost amounting to 820,000*l.*

The rails used on the Liverpool and Manchester road are made of forged iron, in lengths of five yards each, and weigh thirty-five pounds per yard. Every three feet the rails rest on blocks of stone, let into the ground, containing each nearly four cubic feet. Into each block, two holes, six inches deep, and one inch in diameter, are drilled; into these are driven oak plugs, and the cast-iron chains or pedestals, into which the rails are immediately fitted, are firmly spiked down to the plugs, forming a structure of great solidity and strength. The double lines of rails for the carriages, are laid down with mathematical correctness, and consist of four equi-distant rails, four feet eight inches apart, about two inches in breadth, and rising about an inch above the surface. In the formation of the railway, there have been dug out of the different excavations, upwards of three millions of cubic yards of stone, clay, and soil.

THE STEAM-ENGINE.

Why is heat so important in the production of mechanical agents?

Because bodies, whether liquid, solid, or aeriform, exert a certain degree of mechanical force, in the process of enlarging their dimensions, on receiving an accession of heat; and any obstacle which opposes this enlargement, sustains an equivalent pressure. This force is frequently used as a mechanical agent, and has this to recommend it, that it may be produced to almost any degree of intensity, without the expenditure of any other mechanical force in its production.

It is not requisite to enter theoretically into the production of heat, since the subject has already been popularly illustrated in the present work.*

Why is the steam-engine much more intelligible than its name first suggests?

Because it is in fact only a pump, in which the fluid is made to impel the piston, instead of being impelled by it, that is to say, in which the fluid acts as the *power*, instead of being the *resistance*. It may be described simply as a strong barrel or cylinder, with a closely filled piston in it, which is driven up and down by steam, admitted alternately above and below from a suitable boiler; while the end of the piston-rod, at which the whole force may be considered as concentrated, is connected in any convenient way with the work that is to be performed. The power of the engine is of course proportioned to the size or area of the piston, on which the steam acts with a force, according to the density, of from 15 to 100 or more pounds to each square inch. In some of the Cornish mines, there are cylinders and pistons of more than 90 inches in diameter, on which the pressure of the steam equals the efforts of 600 horses.—*Arnott.*

The steam-engines in England represent the power of 320,000 horses, equal to 1,920,000 men, and being, in fact, managed by only 36,000 men, add consequently to the power of our population, 1,884,000 men.

The cost of a steam-engine varies according to its power. The smaller cost nearly 100*l*., for each horse power, the largest not quite 400*l*. The consumption of coal is rated at one bushel, or 84 pounds per hour, for an engine of ten-horse power; the quantity is somewhat less in proportion in engines of great power.

Why is there a large vibrating beam in the steam-engine?

Because, one end being connected with the piston-

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* See Part V., Chemistry.—*Heat*, p. 21 to 35.

rod, is pulled down, while the power of the engine is applied at the other end to any mechanical purpose. Thus, when connected with immense water-pumps, it causes almost a river of water to gush out from the bowels of the earth.

Why are the improved paddle-wheels of steam-boats made to enter the water sideways?

Because they give the propelling stroke direct, whereas the ordinary wheels press the broad face of their paddles on the surface of the water, and thus increase the resistance.

Why are steam-engines of such important use in mining?

Because they speedily raise the water which breaks in on the miners.

The practical adaptation of the steam-engine to mechanical purposes, is considered by Mr. Davies Gilbert as due to Mr. Newcomen, whose inquiries were introduced into Cornwall very early in the last century, and soon superseded the rude machinery which had, till then, been employed for raising water from mines, by the labour of men and horses.

The various applications of steam-power would occupy many pages: if we except its adaptation to the motion of carriages, perhaps few of its effects are more astounding than in the manufacture of iron. Thus, there are factories where this resistless power is seen, with its mechanic claws, seizing masses of iron, and in a few minutes delivering them out again pressed into thin sheets, or cut into bars and ribands, as if the iron had become soft, like clay in the hands of the potter.

The annual product of the foundries of Messrs. Crawshay and Co. in Glamorganshire, is 11,000 tons weight of pig-iron, and 12,000 tons of iron in bars. A steam-engine of the power of 50 horses, and a water-wheel of 50 feet diameter, work the cylindrical blow-

ing-machines, which are indispensably necessary in the use of coke, and the other machinery of the works. This enormous water-wheel is kept in motion by the pressure of 25 tons of water per minute. The establishment employs from 1,500 to 2,000 workmen, forming, with their families, a population of 4,000 persons. The sum total of their wages amounts annually to from 70,000*l.* to 80,000*l.*

Such has been the progressive improvement in the steam-engine, that in 1829, the best engine in Cornwall did ten times the work of any engine in 1778; or each bushel of coals raised 20,000 gallons of water.

M. Dupin estimates the steam-engines of France equivalent to the power of 480,000 workmen turning a winch; and it is calculated by the same writer, that Great Britain possesses, in steam-engines alone, a moving power equivalent to that of 6,400,000 men employed at the windlass.

Why do high pressure differ from low pressure engines?

Because, in high pressure engines the steam is not condensed; but after having acted on the piston, is allowed to blow off into the air; whereas, in low pressure engines it passes into a separate vessel, where it is condensed; on which account, and for other reasons, low pressure engines do not suit a rail-road. High pressure engines occupy less room, require less fuel than low pressure engines, and their power can be increased on emergencies, by merely increasing the fire; but the risk of damage from explosion is considerable. Their principal purpose is to save water, but this is always abundant in navigation.

The principle of high pressure steam-engines depends on the power of steam to expand itself, 5, 10, 20, 30, 40, &c. times beyond its original bulk, by the addition of a given portion of heat, which is effected by increasing the pressure.

Under mean pressure, at the temperature of 212°. (the boiling point) the bulk of steam is 1,800 times that of water; or, as a ready rule for calculation, a cubic inch of water produces about a cubic foot of steam. The latent heat of steam is about 960°.

Why is Brown's Pneumatic Engine a species of steam-engine?

Because its principle is a very sudden expansion and condensation, not of the gases used in the operation, but of the small quantity of water formed by the combustion of the hydrogen, with the oxygen of the atmospheric air, admitted into the cylinder at every stroke of the engine. The difference between this and a steam engine is, that the elastic and condensable fluid is generated at a higher temperature from materials admitted into the cylinder itself. The extent of the vacuum produced must depend on the temperature at which the combustion takes place.—*Notes in Science.*

Why is the explosive engine so called?

Because it is set in motion by the explosion of oil gas and atmospheric air, the mechanical force of the explosion being employed to drive the machinery. Percussion powder, and other substances that explode by contact, may eventually be employed for the same purpose.

RECENT INVENTIONS AND IMPROVEMENTS.

Why is the printing-press invented by Lord Stanhope so superior to the wooden press, or that previously in use?

Because the Stanhope press is composed entirely of iron; the table on which the types rest, and the platten (or surface which gives the impression) are made perfectly level; a beautiful combination of levers is added, to give motion to the screw, causing the platten to descend with increasing rapidity, and consequently with increasing force, till it reaches the type, when a very great power is obtained. There have been, per-

haps, twenty contrivances for obtaining the same effect; but, *as a press*, Lord Stanhope's invention has not been surpassed. Still, it is only a press, and in point of *expedition* has little superiority over its wooden rival, producing 250 impressions per hour.

It is a remarkable fact, that from the invention of printing to the year 1798, a period of nearly three hundred years, no improvement had been introduced into this important art.*

A mere outline of the improvements from this period would occupy many pages. The great triumph in the art has, however, been the substitution of cylindrical machinery for the screw-press. The *suggestion* of this improvement belongs to Mr. W. Nicholson, but the two first *working* machines were erected by Mr. Koenig, for printing the *Times* newspaper, the reader of which was told, on Nov. 28, 1814, that he held in his hand a newspaper printed by machinery, and by the power of steam!

In these machines the type was made to pass under the cylinder, on which was wrapped the sheet of paper, the paper being firmly held to the cylinder by means of tapes; the ink was placed in a cylindrical box, from which it was forced by means of a powerful screw depressing a tightly-fitted piston; thence it fell between two iron rollers; below these were placed a number of other rollers, two of which had, in addition to their rotatory motion, an end motion, *i. e.* a motion in the direction of their length; the whole system of rollers terminated in two, which applied the ink to the types. In order to obtain a great number of impressions from

* Mr. Buckingham saw in a convent on the mountains of Lebanon, a printing-press and Syriac types, from which the monks produce their church-books, quite equal to those at Rome. The press nearly resembled in shape the common printing-press used in England. It is there considered a mystery, as "they had never yet had an European here, who had ever seen the mechanical operation of printing in Europe." Other monks in the same convent were employed in weaving, masonry, carpentry, &c.

the same form, a paper cylinder (*i. e.* the cylinder on which the paper is wrapped) was placed on each side the inking apparatus, the form passing under both. This machine produced 1,100 impressions per hour; subsequent improvements raised them to 1,800 per hour.

The next machine, also by Mr. Koenig, was for printing both sides of the sheet, by conveying the sheet from one paper cylinder to the other. This was made in 1815, and printed 750 sheets on both sides per hour. In the same year Mr. Cowper obtained a patent for curving stereotype plates, for fixing them on a cylinder. Several of these machines, capable of printing 1,000 sheets per hour on both sides, are at work at the present day; and twelve machines on this principle were made for the Bank of England, a short time previous to the recent issue of gold. These machines, though only adapted for stereotype printing, first showed the best method of furnishing, distributing, and applying the ink by rollers.

Messrs. Applegath and Cowper have, however, by their conjoint ingenuity, superseded Mr. Koenig's inventions, and constructed upwards of 60 machines, modified in twenty-five different ways, for printing books, bank-notes, newspapers, &c.: their greatest success has been in printing newspapers. In the *Times* machine, which was planned by Mr. Applegath, the form passes under four printing cylinders, which are fed with sheets of paper by four lads, and after the sheets are printed, they pass into the hands of four other lads; by this contrivance 4,000 sheets per hour are printed on one side.

The comparative produce of the above machines is as follows:—

Stanhope press	- - -	250 impressions per hour.
Koenig's machine	- - -	1,800 *i. e.* 900 on both sides.
Cowper's (stereotype)	- -	2,400 *i. e.* 1,200 ditto.
Applegath and Cowper's (book)		2,000 *i. e.* 1,000 ditto.
Ditto (newspaper) Chronicle	-	2,000
Herald	-	2,400
Times	-	4,000—66 per minute.

We have principally abridged these facts and data from a valuable paper communicated by Mr. Cowper, one of the inventors, to the Royal Institution, and subsequently to the *Quarterly Journal of Science*, in the year 1828.

The machine for printing the *Atlas* newspaper, (each copy of which, in some cases, has contained 40 feet of printed superficies) consists of two larger and two lesser cylinders, put in motion by a steam-engine of 4-horse power, managed by three boys, whose only task is to present the end of the enormous blank sheet to the first cylinder, and to receive it, in a few seconds, printed on both sides, as it is discharged by the last cylinder.

Why will some machines produce paper of indefinite length?

Because in them the pulp is delivered from the trough to an endless web of wire, passing over cylinders, which are turned by steam, or any other prime mover. From the wire web it passes between two rollers to an endless web of felt, which passes over other cylinders, and between two other heavy rollers, for the expression of the water; the paper is thence wound upon a reel, and when a sufficient quantity is received on it, the paper is cut off, and removed to the drying-house. At White Hall Mill, in Derbyshire, a sheet of paper was lately manufactured which measured 13,800 feet in length, 4 feet in width, and would cover an acre and a half of ground.

Why does beating books with a hammer cause the printing to "set off" on the opposite page?

Because the blows suddenly compress the air between the leaves, and create heat which disturbs the ink.

Why has pressing been advantageously substituted for this beating?

Because it renders the books extremely compact and solid, by passing the sheets, when folded, between

a pair of powerful rollers, by which much time is saved, the paper is made smoother, and the compression, though greater, does not disturb the ink. A rolled book will thus be reduced to about five-sixths of the thickness of the same book, if beaten: a shelf, therefore, that will hold fifty books beaten in the usual manner, will hold nearly sixty of such, if rolled.—*Trans. Soc. Arts.*

Why are knives sharpened by being drawn between two horizontal rollers, as in "the patent knife-sharpener?"

Because the rollers revolve freely upon their axis; and at uniform distances are fixed narrow cylinders, or rings of steel, the edges of which are finely cut with file teeth, forming thereby circular files; the edges of these files overlap or intersect each other a little, so that when a knife is drawn between them, it operates on both sides of the edge at once; and as the rollers turn round at the slightest impulse, the peripheries of the circular files get uniformly worn, and consequently will last a long time.

Why does the transparent dial of St. Giles's church, London, light itself with gas as soon as the sun sets at night, and put out the light when the sun rises in the morning?

Because a wheel is connected with the clock, which makes but one revolution in twenty-four hours; and on this is placed a series of pins, which, by their revolution with the wheel, tend to raise a lever connected both with a gas-cock and a movable screen. The gas which illuminates the dial is burning at all times, but the consumption during the day is comparatively small, as the lever opens and shuts the aperture by the motion of the large wheel; so that a person in the immediate neighbourhood of the clock would see little more than a faint indication of flame during the day light; but at evening the lever opens the aperture to its full size, and lets forth a brilliant flame. The movable screen completely cuts off any portion of light

which might otherwise pass from the partially closed burner.—*Mr. C. F. Partington, in the Atlas Newspaper.*

Why are the faces of many new public clocks made of stone instead of metal?

Because stone being an absorbent, and not so good a conductor of heat as metal, the paint adheres better and lasts longer, and does not require to be renewed so often as on the copper dial. Another advantage of the stone dial is, that the centre can be sunk, and the hour hand made to traverse in the sinking. This enables the minute-hand to be close to the figures, and then almost all error from the effect of parallax is avoided, which in the copper dial is very considerable; especially when the minute-hand points at or near 15 and 45 minutes, and the hands are both above the dial. In the stone dials of Chelsea new church, and the Royal Mews, Pimlico, the figures are cut in the stone, and sunk about the eighth of an inch, after the manner of the Egyptian monuments, from which was derived the idea. By this method, supposing the dial accurately divided, and the figures well shaped in the first instance, they will always remain so.—*Mec. Mag.*

The originator of this improvement is Mr. Vulliamy, the eminent horologist.

Why is the Diorama so called?

Because of its origin from the Greek, signifying two views, of which this exhibition consists. These pictures are painted in solid, and in transparency, arranged and lighted in a peculiar manner, so as to exhibit changes of light and shade, and a variety of natural phenomena. The means by which these changes are effected, may be explained as follows:—The contrivance is partly optical, partly mechanical; and consists in placing the pictures within a building so constructed, that the saloon containing the spectators may revolve at intervals, for the purpose of bringing in succession two distinct pictures into the field of view, without the necessity of the spectators removing from

their seats; while the scenery itself remains stationary, and the pictures therefore admit of an improved method of distributing light, by which they are illuminated, so as to produce the effects of a variable picture. This is performed by means of a number of transparent and movable blinds, some of which are placed behind the picture for the purpose of intercepting and changing the colour of the rays of light, which are permitted to pass through the semi-transparent parts of the picture. Similar blinds are also situated above and in front of the pictures, so as to be movable by the aid of cords, and by that means to distribute or direct the rays of light which are permitted to fall upon the front of the scene.

The extent of revolving motion given to the saloon, is an arc of about 73°; and during the time that the audience is thus passing round, no person is permitted to go in or out. The revolution of the saloon is effected by means of a sector, or portion of a wheel, having teeth formed upon its edge; these work in a series of wheels and pinions, so that one man placed at a winch is enabled to give motion to the whole.

The space between the saloon and each of the two pictures is occupied on either side by a partition, forming a kind of avenue, proportioned in width to the size of the picture; without such a precaution, the eye of the spectator being thirty or forty feet distant from the canvass, would, by any thing intervening, be estranged from the object. The views are eighty-six feet in length and forty-five feet in height.—*Atlas.*

END OF PART VII.

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